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EVALUATION OF AIRCRAFT EQUIPMENT MONITORING DEVICES, PROCEDURES--ETC(U)

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EVALUATION OF AIRCRAFT EQUIPMENT MONITORING DEVICES: PROCEDURES, AND TECHNIQUES

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July 1978

Final Report

Approved for public release; distribution unlimited.

Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

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APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

This report provides insight into a problem that has perplexed Army aviation reliability and maintainability specialists; i.e., obtaining correlation between field-reported cause of failure and actual cause of failure. Through correlation of equipment improvement recommendations (field perception of cause of failure) and disassembly inspection reports (DIR) (actual cause of failure), some understanding is presented of the adequacy of field personnel to accurately describe the actual cause of a failure.

There is no feedback of DIR or other teardown analysis results into the Army's maintenance data system. Hence, data that would be very useful to new development or product improvement programs are not readily available to engineers except by an extensive data gathering and analysis effort.

The reader is cautioned that the sample size for some of the judgements made in this report are small and hence are suspect. However, this report does provide a basis for a more thorough analysis of the utility of the current Army aircraft maintenance data gathering and analysis programs.

Mr. Donald R. Artis, Jr., Aeronautical Systems Division, served as Contracting Officer's representative (technical) for this program with Mr. G. William Hogg providing assistance.

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This report presents the results of a study of current diagnostic techniques and procedures used at the aviation unit maintenance level for Army helicopters.

A projection is provided to show the potential improvement which could be attained in reliability (R), availability (A), and direct support costs (C) for selected helicopter components through (cont)

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improved diagnostic methods. This potential would be realized if the current field diagnostic capability were improved to the effectiveness represented by the engineering teardown underlying the Disassembly and Inspection Reports (DIRs). The validity of current diagnostic monitoring devices, techniques and procedures is presented in terms of comparison of the unit removal reason to the actual DIR finding upon teardown. A relationship of primary fault indicators to the degree of aircraft damage or loss of mission effectiveness is also presented.

PREFACE

This final report is submitted in partial fulfillment of contract DAAJ02-77-C-0052, performed under the auspices of the Applied Technology Laboratory (ATL), U.S. Army Research and Technology Laboratories (AVRADCOM), at Fort Eustis, Virginia. The overall objective of this contract was "to investigate the effectiveness and impact of current Army helicopter diagnostic and condition monitoring (D&CM) devices, procedures and techniques on maintenance support cost and aircraft downtime."

We acknowledge the technical support and encouragement of personnel at ATL, especially Mr. Donald Artis, as COR, and Mr. G. William Hogg. We also appreciate the cooperation and assistance of other Army personnel from the Product Assurance and Aviation Safety Liaison office at TSARCOM; the 5th Transportation BN, 101st Airborne Division at Fort Campbell, Ky.; and the Corpus Christi Army Depot at Corpus Christi, Texas.

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I. INTRODUCTION

BACKGROUND

Personnel concerned with the operation and support (O&S) of Army aircraft have long recognized the advantages of monitoring equipment performance to maintain the highest standards of equipment integrity in the operating environment(s). There is of course a corresponding interest in achieving such standards of integrity at reasonable dollar expenditure.

Current techniques of condition monitoring include relatively formal methods of measuring such key parameters as engine temperature, oil pressure and contamination, engine RPM, etc. These also include relatively informal methods such as pilot attention to excessive vibration or unusual noise. The composite of such information is being continuously reviewed by the pilot or by unit maintenance personnel, and serves as a basis for a continuing overall assessment of equipment condition. Thus, the information base currently being generated on aircraft equipment condition, coupled with the existing criteria and procedures for acting on that information, provides the rationale for an important part of the observed pattern of equipment removal and/or repair.

The objectives of this study were:

1. To investigate the effectiveness of the existing diagnostic and condition monitoring (D&CM) devices, procedures, and techniques in terms of the aircraft downtime and maintenance support costs.

2. To determine the impact of any existing D&CM deficiencies on downtime and maintenance support costs.

3. To identify the most effective D&CM techniques.

SCOPE OF STUDY

Within the resources available for this study the emphasis was placed on the development of a methodology for such an assessment, and on a limited application of that methodology to specific components of specific aircraft, using data now available through Army channels. This approach placed no limitation on the generality of the methodology itself, and care has been taken to assure that the methods described herein are generally applicable to all major equipments on all Army aircraft. Two considerations dominated the selection of a "test bed" around which the investigation was structured:

1. The major dynamic components of an Army helicopter are critical with respect to both safety and mission success. An in-flight failure generally leads to mission abort as a minimum, and can result in major accident or injury. Furthermore, these components account for 60-80 percent of direct O&S costs for Army helicopters. Thus the value of any single D&CM technique, or any combination of such techniques, must be based principally on its usefulness with respect to the major dynamic components of the aircraft.

2. From the standpoint of data availability, it was necessary to limit attention to those aircraft which had been in service for a sufficient time to generate a reasonably complete experience base.

From these two considerations, the focus of this study was placed on the engines, transmissions and gearboxes of the UH-1H, AH-1G, OH-58A, and CH-47B/C aircraft.

II. OVERVIEW OF ANALYSIS LOGIC

DEFINITION OF PROBLEM

As an aircraft undergoes continued utilization in the field, each dynamic component in the aircraft carries out its own individual duty cycle and, as it ages, it ultimately undergoes a degradation in the quality of its performance. Over a period of time each component is thus exposed to an increasing risk that it will prove unserviceable, or will fail catastrophically while in use.

The removal of a dynamic component may result from any of a broad range of causes, ranging from inherent failure of the equipment to damage from external sources to removal for administrative reasons. These causes have been grouped by COBRO for convenience into 13 major categories. The breakdown of these 13 categories is shown in Section III, p. 23; the Army's Removal Cause Codes are shown in Appendix A, subdivided into the 13 categories. The significant removals from the standpoint of diagnostics are those relating to inherent failure, designated by Categories 1-6 and certain types of Category 7-11 removals.

For major dynamic components on the selected aircraft, the Army's MIRF (Major Item Removal Frequency) report tabulates all removals and indicates the assigned cause for each. The cause code, as reported by MIRF, represents the summary conclusions drawn by unit maintenance, under field conditions, making use of all currently available D&CM techniques and procedures. It thus illustrates the de facto field operation of the composite diagnostic capability currently available at aviation unit maintenance (AVUM). The conclusions of field personnel may be correct as to the specific cause of an inherent failure; they may be partially correct, in that the component did suffer an inherent failure but the diagnosis of the specific cause within that category may be wrong; or they may be wrong--that is, the removal at the time shown was not valid. If one could compare the results of field diagnostics against a diagnostic benchmark as defined in some way, it would be possible to assess the adequacy of the current D&CM techniques and procedures.

Often major components removed from Army aircraft are forwarded to depot for a complete teardown and a detailed engineering analysis of their condition. The results of such an analysis, as documented by the Disassembly and Inspection Reports (DIRs), represent as close an approximation to a "perfect" diagnosis as is currently possible, and thence can be viewed as a benchmark against which the MIRF-reported diagnosis can be compared.

The logic of the problem for analysis can be visualized by reference to Table 1. Of all of the components of a given type (say, engines) which are examined in the field, a subgroup (Block A) will be removed for what is diagnosed in the field as one of the six modes of inherent failure. For simplicity, the breakdown into specific cause codes in Block A is not shown. A certain fraction of these will ultimately be selected by AVUM for engineering analysis at depot, and the DIR findings will be reported as shown in Blocks A-1, A-2, and A-3. The engines falling in Block A-2 represent those which are correctly diagnosed in the field as having suffered an inherent type of failure. Those falling in Block A-1 should have been removed earlier, and thus have incurred a cost through staying in service too long, represented by decreased R/A and aircraft safety. Those falling in Block A-3 represent premature removals, with a concomitant cost represented by a loss of useful life. For a perfect field diagnostic system applied to N_A engines removed for inherent failure, we would expect the DIR verdicts to be distributed as follows:

Block	A-1	A-2	A-3
Number	0	N_A	0

Any deviations from this distribution represent an increase in cost.

Similarly, Block B represents the complement of Block A, that is, those engines which were not diagnosed as having suffered an inherent failure. Thus $N_B = N - N_A$, where N is the total number of engines in the fleet. If the N_B engines were to be submitted to depot for diagnosis, we would expect--again assuming perfect field diagnosis--a distribution as follows:

Block	B-1	B-2	B-3
Number	0	0	N_B

Block C (which is logically a subset of Block B) is not applicable to the present analysis, since it involves removals for reasons other than material condition.

TABLE 1. DIAGNOSTIC ERROR LOGIC

	DIR FINDINGS FOR ENGINES		
	Inherent Failure		No Failure
Field Diagnosis	1. Should have been removed earlier	2. Should be removed now	3. Should not be removed now
A. Should be removed for an inherent type of failure (MIRF reported)	A-1 Removed too late--(added risk cost)	A-2 Valid diagnosis (minimum cost)	A-3 Removed too early (added cost due to low utilization)
B. Should not be removed for an inherent type of failure	B-1 No DIRs performed under present procedures	B-2	B-3
C. Should be removed for other reasons	C-1 No DIRs performed under present procedures	C-2	C-3

The analytic problem to be addressed is to compare the field assessment of equipment condition against the DIR assessment; to evaluate the impact of any differences in terms of the effect on system R, A, and C; to determine the overall potential for improvement of field diagnostics; and to determine which field diagnostic techniques are most valuable in terms of their contribution to field accuracy.

Because of certain data limitations, the analysis will necessarily tend to be somewhat biased, with the exception of those removals due to aircraft accident, etc. The only group of components which may be selected for teardown analysis are those which, in the opinion of AVUM personnel, have suffered a failure. These are represented by row A in Table 1. In general, those which are presumed by field maintenance not to have suffered an inherent failure or operational or environmental anomaly are not candidates for DIR. Consequently, any errors of omission by the field maintenance--where a component is not removed when it should be removed--will not be caught by DIR. The removal of this bias is a fairly straightforward research process, but it will require data not now available and is consequently outside the scope of this study. Recommendations for expanding the present assessment to include those components in Row B are presented elsewhere in this report.

Thus, the focus of the present study is on the validity or lack of validity of field decisions which led to removal of components for inherent failure, on the potential for improvement of those decisions, and on the cost of errors in the decisions.

GENERAL APPROACH TO PROBLEM

Processing of Empirical Field Removal Data

The MIRF data provided, for each component type (e.g., the AH-1G engine), a remove/replace history, which as a sequence of actions over time is shown in Figure 1. Each interval represents, for that component, a "time-between-removals," and the average length of the interval for a given component is the MTBR for that component.

The distributions for the components were determined by plotting these individual removal intervals on Weibull graph paper and fitting a straight line to the resultant points. The slope and intercept of that line provided a basis for estimating the parameters of the Weibull distribution which best described the life characteristics of that component. A typical Weibull plot is shown in Figure 2. The Weibull plots for all components in the study are incorporated in Appendix B for reference.

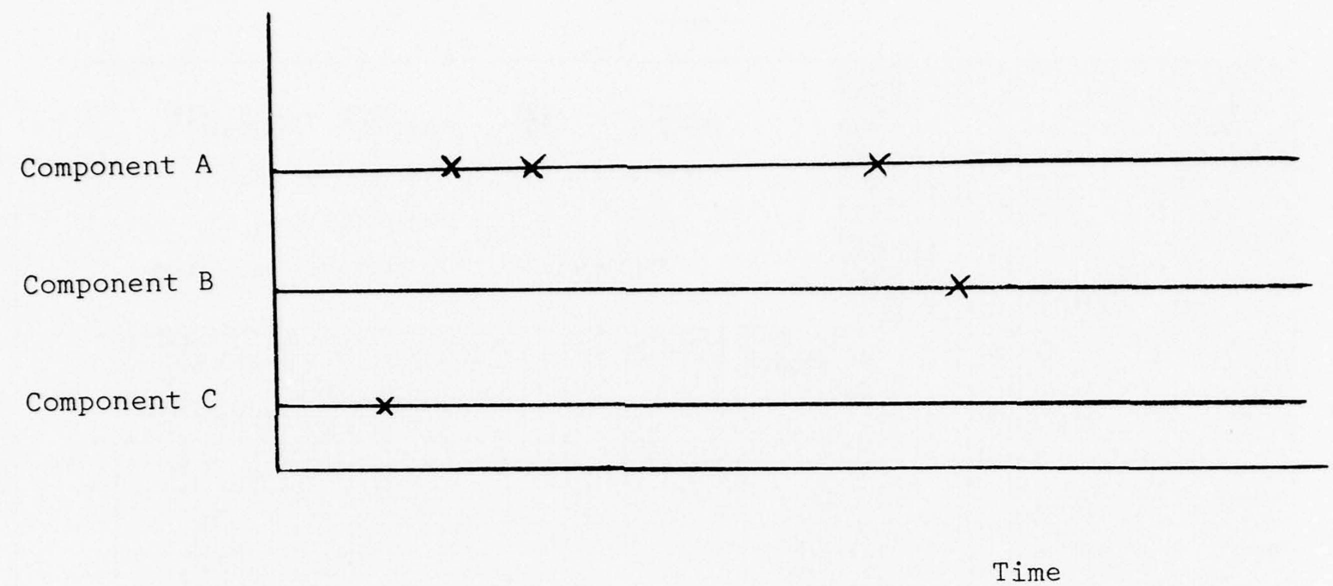

FIGURE 1. ILLUSTRATIVE TIME SEQUENCE OF COMPONENT REMOVALS AS DRAWN FROM MIRF REPORT

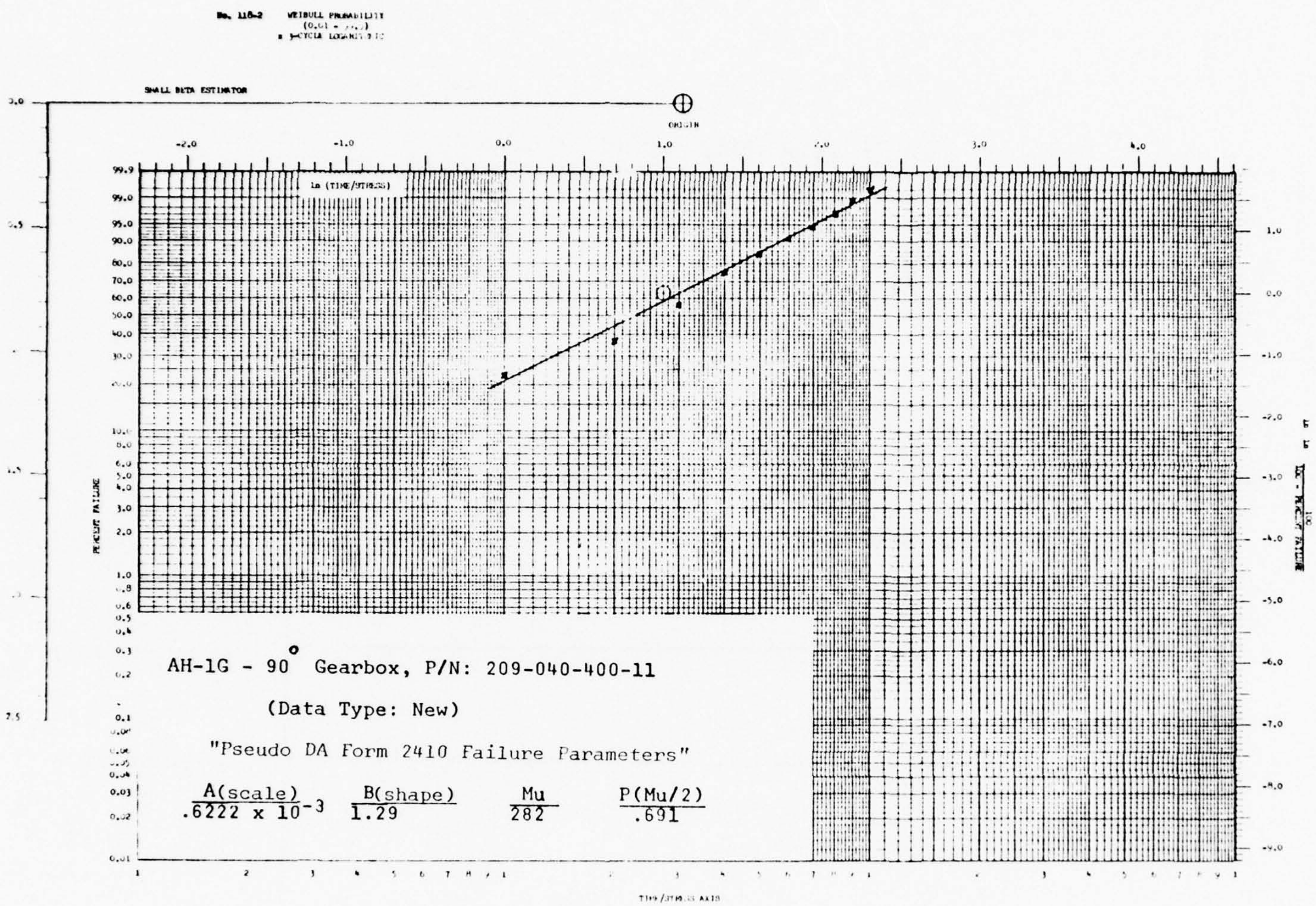

FIGURE 2. WEIBULL PLOT OF REMOVAL DISTRIBUTION FOR GEARBOX

Analysis of R, A, C Consequences of De Facto Field Removals

The data processing steps outlined above provided the Weibull life characteristics for each component. That information, coupled with the plan for use for the component (e.g., its mission duration, frequency, duty cycle), the support plan (e.g., inspection intervals, TBO's), and the costs of labor and material involved in each type of maintenance/removal action, provided the input information base necessary for application of the Army's Analytic Methodology for System Evaluation and Control (AMSEC). 1/ This methodology was used to deliver as output predictive estimates of component/system reliability (R), availavility (A), and life cycle direct support cost (C). Thus, an estimate was obtained of R/A/C corresponding to the de facto field removal policy for components.

Development of Pseudo-DA Form 2410s for removal as Designated by DIRs

The DIRs provided a basis for generating a set of pseudo-DA Form 2410 reports documenting the number of flight hours when the component would have been removed if AVUM had had the available information from the teardown analysis. The set of pseudo-DA Form 2410s thus show the removal times which would have been experienced if DIR diagnostic capability had been available to AVUM.

To determine the removal times for the pseudo-DA Form 2410s, three different cases were considered:

1. The DIRs agree with the field removal actions (Block A-2, Table 1)--In these cases the actual flight hours at removal, as reported by MIRF, were carried over into the pseudo-DA Form 2410 documentation.

2. The DIRs indicate that the field removals were made too early--that is, the components had a residual life which should have been utilized but was not. In these cases the actual removals were redistributed forward over time, and their pseudo removal was delayed until a time which would have been designated by AVUM, assuming that AVUM had had available the DIR teardown findings. A mathematical algorithm was developed for accomplishing this redistribution (see

1/ For a full description of AMSEC, see COBRO Corporation TR 9-14, "AMSEC User's Guide," June 1976, published by USAAVSCOM, St. Louis, Missouri.

Section IV) and the new removal times were carried forward to the pseudo-MIRF documentation.

3. The DIR indicates that the field removals should have been made earlier--in such cases the actual removals could be redistributed backward over time through the use of an algorithm analogous to that developed for case 2 above. However, under existing procedures DIRs are only carried out on components which are presented by AVUM as having already failed. Components not thought by AVUM to have failed are not reviewed by DIR, so there is no opportunity for the DIR to recommend a removal for a component still in service. Thus, case 3 did not occur in the data under investigation.

Processing of Pseudo-DA Form 2410s

The set of pseudo-DA Form 2410s developed through the preceding steps was provided in a format identical to that of true MIRFs. Processing of this data to obtain the MTBR and Weibull life characteristics was carried out in the same way. The Weibull plots developed from the pseudo-DA Form 2410s are included in Appendix B.

Analysis of Consequences of DIR-Dictated Field Removals

The Weibull life characteristics for each component, as generated from the pseudo-DA Form 2410s, were next entered into the AMSEC methodology, and estimates were developed for the projected R/A/C under the assumption that a diagnostic capability equivalent to that represented by the DIR was available at AVUM.

Comparison of AMSEC Outputs

A comparison was made between the projected R/A/C values under the existing field diagnostic situation and the corresponding R/A/C values as projected for the "near-perfect" (DIR) field diagnostic situation. On this basis an estimate was provided of the potential for improvement in R/A/C if field diagnostics were improved. The logic flow for this entire sequence of steps is shown in Figure 3. The results of the analysis are shown in Section V. It should be kept in mind that the savings shown by this comparison are based only on the false-alarm errors at AVUM; an estimate of the improvement that could be attained through removal of false-clear errors--where AVUM concluded

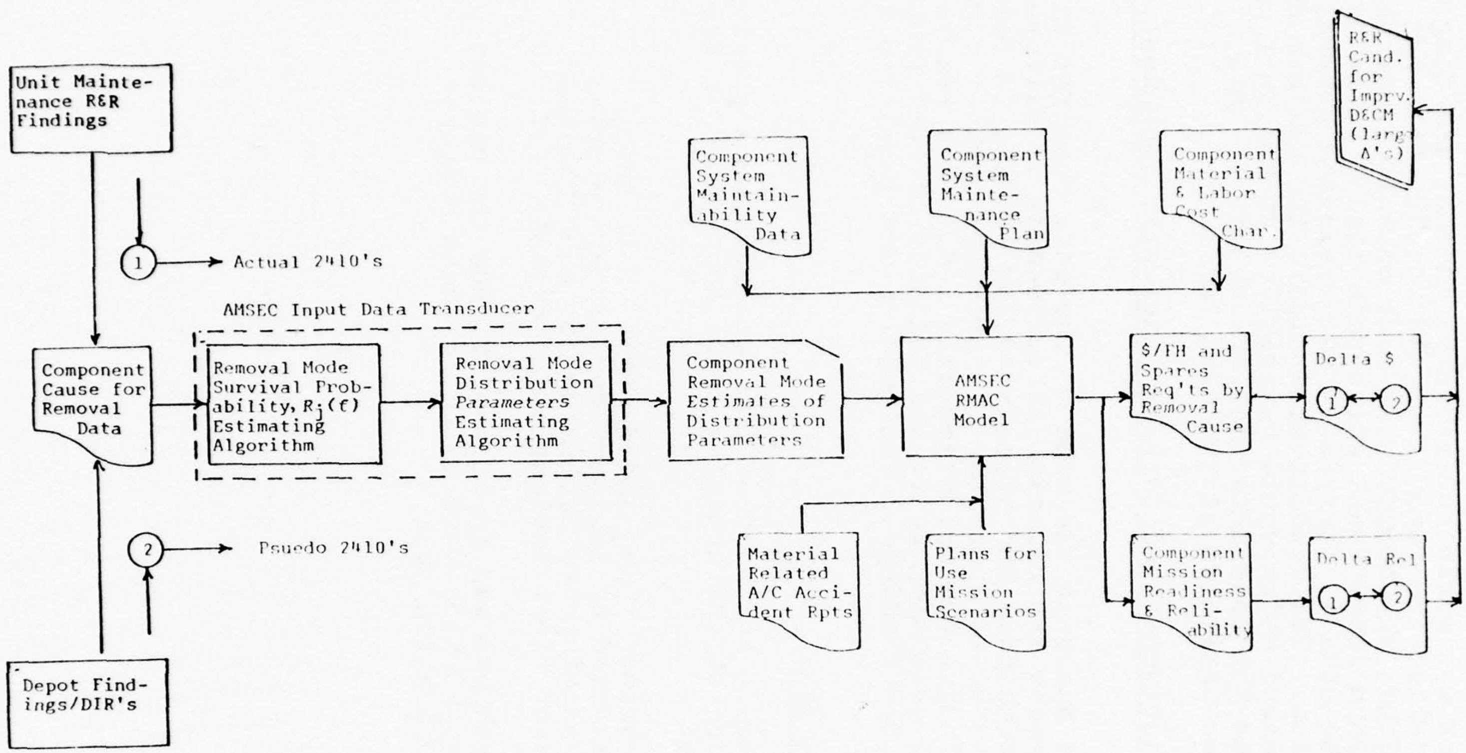

FIGURE 3. STUDY LOGIC FOR ASSESSMENT OF D&CM DEVICES, PROCEDURES, AND TECHNIQUES

that operation was satisfactory where in fact the diagnosis should have called for removal--would require data not now available. Thus, the comparisons made in this study do not show the maximum improvement which potentially could be realized since the data is limited to only removals generated by some indication. The results do indicate the maximum diagnostic effectiveness which could be realized at the unit maintenance level and the associated dollar savings if this effectiveness could be instituted at the AVUM level.

Relative Effectiveness of Current Diagnostic Techniques, Procedures

A statistical analysis was made of the data base for this project to determine the relative effectiveness of different diagnostic techniques and procedures now in use, in terms of their validity as an indicator of time-for-removal. Each of the primary indicators which actually led to the removal of a component was evaluated as to the validity of that removal in light of the DIR findings. The results are tabulated in Section V.

Auxiliary Analyses

Several secondary analyses of the data base were carried out as a by-product of the study, and are documented in Section V. These include:

- The various types and degrees of mishaps, as reported by accident and mishap reports, were examined to determine for each the most dominant first indication of trouble (FIT).

- A breakdown was developed to show the percent of removals which were valid for each component by authorization type.

III. DATA SOURCES AND COLLECTION TECHNIQUES

Five major sources of data were identified which had a direct bearing upon the analysis. A detailed review and assessment of these sources was made with respect to the aircraft/components under investigation. A description of these sources, along with any additional information surrounding the techniques used and/or the problems encountered, follows.

MAJOR ITEM REMOVAL FREQUENCY (MIRF) REPORTS

The basic input information on which this study draws is the MIRF report data as derived from the Army Maintenance Management System (TAMMS) DA Form 2410. The MIRF reports present a computerized listing of the total number of removals by removal cause (as determined by the aviation unit maintenance level) for all 2410 components as reported through TAMMS. These listings also distribute each of the removal causes into flight-hour increments (every 100 hours) over which an item operated before it was replaced. This information is separated to provide removals for both new items and for those that have been previously overhauled.

The MIRF data provides a basis for an estimate of the inherent life characteristics of each of the major components by removal cause category. Parameters of interest include the mean life of the component with respect to a given removal cause and the probability that the component will survive for a given use period; e.g., half its mean life. Together, assuming a two parameter Weibull format, these parameters define the shape of the life distribution for a component.

The computerized MIRF report listings are available from the U.S. Army Troop Support and Readiness Command (TSARCOM), Product Assurance Directorate, on a request basis. An example of the MIRF format is displayed in Table 2.

TABLE 2. EXAMPLE OF MIRF FORMAT

****** FAILURES *********************************** FIRST REMUVAL - NEW ITEM ***

FUNCTIONAL GROUP 03 POWER PLANTS AND RELATED SYSTEMS ILLUS ITEM DOT CODE MAINT LEVEL SOURCE CODE

PUMP,FUEL,AUXILIARY FSN 29109917053 PN 114P40101 MFR CODE USED ON MODELS RECCV CODE

NUMBER OF REMOVALS DURING FLIGHT HOUR INTERVAL BY FAILURE CODES

FLIGHT HOUR INTERVALS

FAIL CODE DESCRIPTION	0000 0099	0100 0199	0200 0299	0300 0399	0400 0499	0500 0599	0600 0699	0700 0799	0800 0899	0900 0999	1000 1099	1100 1199	1200 1299	1300 1399	1400 1499	1500 1599	1600 1699	ABOVE 1700	AVG TSN	% TOTAL
255 NO OUTPUT						1													560.0	5.3
374 INTERNAL FAILURE	3		2	3	2	3		1		1									395.6	78.9
381 LEAKING	1																		.0	5.3
503 SUDDEN STOP			1																207.0	5.3
901 INTERMITTENT				1															334.0	5.3

****** FAILURES *************************************** SUMMARY BY FLIGHT HOUR INTERVAL **

	0000 0099	0100 0199	0200 0299	0300 0399	0400 0499	0500 0599	0600 0699	0700 0799	0800 0899	0900 0999	1000 1099	1100 1199	1200 1299	1300 1399	1400 1499	1500 1599	1600 1699	ABOVE 1700
TOTAL IN INTERVAL	4		3	4	2	4		1		1								
CUMULATIVE TOTAL	4	4	7	11	13	17	17	18	18	19	19	19	19	19	19	19	19	19
PERCENT IN INTERVAL	21.1	.0	15.8	21.1	10.5	21.1	.0	5.3	.0	5.3	.0	.0	.0	.0	.0	.0	.0	.0
CUMULATIVE PERCENT	21.1	21.1	36.8	57.9	68.4	89.5	89.5	94.7	94.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In order to provide the estimate of the inherent failure life characteristics of a component, it was first necessary to categorize the 2410 removal codes into failure and nonfailure classifications. A numerical listing of the Army's reasons for removal and the removal category to which each was assigned are presented in Appendix A. Table 3 presents a list of the 13 removal categories used in this analysis. The definitions of these categories are as follows:

- Categories 1-6 represent removals because of inherent failure of the component.

- Categories 7-11 deal with removals because of battle casualties or improper maintenance operation.

- Category 12 represents planned removals (TBOs) in accordance with specified criteria. These removals represent the impact of maintenance policy on removal data.

- Category 13 represents removals stemming from supply convenience and were considered to be the subject of administrative action.

Failure categories 1-6 represent catastrophic equipment malfunctions which could impact component mission reliability, availability, spares provisioning and cost, and which are the basis for estimates of the inherent life characteristics of the component. Also failure categories 1-6 are the one group that would be significantly impacted by the introduction of new diagnostic devices. Therefore, this analysis focusses on the effect of the use of existing or new diagnostic devices on failure categories 1-6, and only addresses the nonfailure removal categories 7-11 to the extent that they would have been initially classified as failure had diagnostic capability been available at the removal level.

Table 4 presents a summation of the total number of removals in categories 1-6 for both new and prior overhauled components under investigation. This data covers the period 1 January 1964 through 1 July 1976.

DISASSEMBLY INSPECTION REPORTS (DIRs)

The DIR data is currently being reported on Form 391 (see Figure 4). The generation of a DIR may come about as a result of one of the following authorizations:

TABLE 3. MAJOR COMPONENT REMOVAL CATEGORIES

01	QUALITY CONTROL Defective Material
02	OBSERVATION Broken or malfunctioning
03	MEASUREMENT Out-of-tolerance
04	DIAGNOSTICS, INSTRUMENTS Status tests, measures
05	SEALS, LEAKS Excessive leaking
06	FAILURE Physical break, rupture, seizure
07	MAINTENANCE Erroneous actions
08	ENVIRONMENT Foreign object contamination
09	CRASH, BATTLE ACCIDENT Physical damage during encounter
10	OPERATIONS Overstress
11	OTHER Not covered by above
12	MAINTENANCE Scheduled actions
13	SUPPLY/CONVENIENCE Administrative, erroneous actions

TABLE 4. NUMBER OF REMOVALS (NEW ITEM AND ONE PRIOR OVERHAUL)*

Aircraft Model	Component Nomenclature	Component Part Number	Number of Removals Generated by Component Failure (Sum of Cat 1-6)	
			New Item	1 Prior OH
AH-1G	Engine, T53L13B	1-000-060-10	95	89
	Engine, T53L13	1-000-060-03	25	27
	Engine, T53L13A	1-000-060-08	239	214
	Main XMSN	204-040-009-65	21	14
	Main XMSN	204-040-016-5	21	28
	Main XMSN	204-040-016-1	62	86
	90° Gearbox	204-040-012-13	210	181
	90° Gearbox	209-040-400-11	182	20
	42° Gearbox	204-040-003-37	296	208
OH-58A	Engine, T63A700	6874201	295	217
	Main XMSN	206-040-003-5	147	--
	T/R Gearbox	206-040-400-9	44	--
	T/R Gearbox	206-040-400-7	344	--
CH-47B	Engine, T55L7C	2-000-030-22	--	42
	Engine XMSN	114D600120	12	22
	Engine XMSN	114D600119	5	21
	Fwd XMSN	114D12003	12	2
	Aft XMSN	114D200126	--	20
CH-47C	Engine, T55L7C	2-000-030-22	20	59
	Engine, T55L11	2-001-020-01	91	--
	Engine, T55L11A	2-001-020-05	7	17
	Engine XMSN	114D62003	27	9
	Engine XMSN	114D62002	93	--
	Engine XMSN	114D62001	67	--
	Fwd XMSN	114D12003	62	--
	Fwd XMSN	114D1200-5	7	25
	Fwd XMSN	114D1200-6	0	0
	Fwd XMSN	114D1200-7	0	6
	Aft XMSN	114D2200-7	5	28
	Aft XMSN	114D2200-8	2	0
	Aft XMSN	114D2200-9	1	2
	Aft XMSN	114D2200-5	22	--
UH-1H	Engine, T53L13	1-000-060-03	19	56
	Engine, T53L13A	1-000-060-08	584	542
	Engine, T53L13B	1-000-060-10	173	329
	Main XMSN	204-040-016-5	110	68
	Main XMSN	204-040-001-17	30	40
	Main XMSN	204-040-016-3	12	33
	Main XMSN	204-040-016-1	97	184
	90° Gearbox	204-040-012-13	1031	844
	42° Gearbox	204-040-003-37	900	526

*Generated from component failure categories 1-6 --Data extracted from TAMMS Major Item Removal Frequency data for period 1 Jan 1964-1 July 1976.

DISASSEMBLY INSPECTION REPORT

1. REPORTING ACTIVITY (UIC/FMC)
2. OPERATING ACTIVITY (UIC/FMC)
3. AIRCRAFT SERIAL NO
4. AIRCRAFT TYPE & MODEL
5. COMPONENT NOMENCLATURE
6. COMPONENT PART NO
7. COMPONENT SERIAL NO
8. FMC
9. DATE REMOVED DD/MM/YY
10. TSN (HRS)
11. TSO (HRS)
12. PREV O/H'S
13. DATE LAST O/H MM/YY
14. LAST O/H ACTIVITY (UIC/FMC)
15. REASON FOR REMOVAL
16. REMOVAL CODE
17. 2410 IDENTIFICATION NO
18. EIR, ASOAP OR DIRECTIVE IDENTIFICATION

19. FINDINGS				20. T/C ITEM GENERAL CONDITION		
NO DISCREPANCY	MFG/DESIGN DISCREPANCY	MAINT/OPER DISCREPANCY	FOREIGN OBJ DAMAGE	GOOD	FAIR	POOR
Z	B	N	F	G	F	P

29. DESCRIPTION OF DEFECT AND/OR REMARKS

21. PART NO OF PRIMARY FAILED PART	22. FAIL CODE	23. QUANTITY REPAIR	NON-REP

24. PART NOs OF OTHER DISCREPANT PARTS	25. COND CODE	26. QUANTITY REPAIR	NON-REP

27. DO PARTS MATCH TM? ☐ YES (Y) ☐ NO (N)
28. SUPPORTING DOCUMENTS ATTACHED? ☐ YES (Y) ☐ NO (N)

30. CONCLUSIONS
31. RECOMMENDATIONS
32. PREPARED BY
33. APPROVED BY
34. DATE DD/MM/YY

SAV-HQ Form 391 (Test)
1 May 75

Edition of 25 Nov 66, may be used.

FIGURE 4. DISASSEMBLY INSPECTION REPORT

1. Equipment Improvement Recommendation (EIR) exhibits

2. TSARCOM directive

3. U.S. Army aircraft mishap

4. U.S. Army Oil Analysis Program (AOAP)

DIR represents a factual failure analysis through engineering, analytical, and diagnostic procedures. The results provide a detailed account of exactly what item of a particular component failed and why. For this reason, the DIR was an important input for the present study, and a significant amount of attention was focussed upon the retrieval of all pertinent information reported. Therefore, a manual review of the information on Form 391 was made for all available DIRs for the respective aircraft/components under investigation covering the period January 1972 through October 1977. The reporting of a teardown analysis relating to Army mishaps is provided on Form 946 (see Figures 5 and 6). All available 946 forms were also reviewed and incorporated in the data base.

This DIR data made available a description of the apparent defect (mechanical fatigue, spalling, etc.) and the conclusions of the investigating engineer. Also, conclusions and recommendations relating to significant problem areas or trends noted by the laboratory personnel or the investigating engineer were available. Data elements extracted from DIRs for this study are as follows:

a. Aircraft model

b. Component nomenclature and part number

c. Time since new

d. Time since last overhaul

e. Number of preceding overhauls

f. Reason for removal (DA Form 2410)

g. Findings code (B - basic discrepancy, design; N - maintenance or extrinsic inducement; F - foreign object damage; Z - no discrepancy; 0 - Other

h. Primary part that failed

TECHNICAL REPORT OF U.S. ARMY AIRCRAFT MISHAP TEARDOWN ANALYSIS	CONTROL NUMBER USAAAVS THEATER

1. AIRCRAFT

a. MODEL	b. S/N	c. TIME SINCE NEW	d. TIME SINCE O/H	e. OVERHAUL ACTIVITY AND DATE

2. OPERATIONAL CONTROL: UIC:

3. COMPONENTS RECEIVED:

	a. NOMENCLATURE	b. PART NUMBER	c. FSN	d. S/N	e. OPERATING TIME
(1)					
(2)					
(3)					
(4)					
(5)					

f. DATE RECEIVED: g. TRANS-MODE: (1) ☐ LAND (2) ☐ AIR (3) ☐ SEA

4. SHIPPING CONDITIONS: SPECIFY:

a. ☐ GOOD b. ☐ POOR

5. REMARKS:

6. FINDINGS:

☐ BASIC (MFG/DESIGN) DISCREPANCY ☐ NON-BASIC (MAINT/OPER) DISCREPANCY ☐ FOREIGN OBJECT DAMAGE ☐ NONE ☐ OTHER

7. FAILED OR MALFUNCTIONED MATERIEL

DID PART NUMBER OF FAILED OR MALFUNCTIONED MATERIEL MATCH THAT LISTED IN TM? YES 1 ☐ NO 0 ☐ UNK ? ☐

(IF "NO" OR "UNK", SPECIFY IN BLOCK 8D, EXPLANATION).

IDENTIFICATION AND HISTORICAL DATA	A. MAJOR COMPONENT	B. PART
(1). NOMENCLATURE		
(2). TYPE, MODEL, SERIES		
(3). PART NUMBER		
(4). FSN		
(5). MFG CODE		
(6). TM DATA:		
(A). TM NUMBER		X
(B). DATE		X
(C). FUNCTIONAL GROUP		X
(D). FIGURE NUMBER		
(E). INDEX NUMBER		
(7). SERIAL NUMBER		

AIRCRAFT MISHAP CASE NO.				OTHER AIRCRAFT	
YR MO DA	TIME	A/C SERIAL		T/M/S	SERIAL

DRXAD Form 946, 1 Feb 72

FIGURE 5. TECHNICAL REPORT OF U.S. ARMY AIRCRAFT MISHAP (FRONT) (TEARDOWN ANALYSIS)

TECHNICAL REPORT OF U.S. ARMY AIRCRAFT MISHAP TEARDOWN ANALYSIS	CONTROL NUMBER USAAAVS THEATER

(8) TAMMS DATA:		
(A) NO. OF OVERHAULS		
(B) HR. SINCE OVERHAUL		
(C) HR. SINCE NEW		
(D) HR. SINCE LAST INSTALL.		
(E) LAST OVERHAUL-FACILITY		
(9) LAST SPECIAL INSPECTION: (INDICATE FOR THESE COMPONENT(S))		
(A) TYPE		
(B) DATE		
(C) HOURS SINCE		
(10) TYPE FAILURE		
(11) CAUSE OF FAILURE		
(12) EIR CONTROL NUMBER		

8. ANALYSIS

A. POL CLASS	TYPE	SAMPLE				CONTAMINATED			CAUSATIVE ROLE				FILTER COND.			
		(1) YES	(0) NO	DATE TAKEN YR MO DAY	ANALYSIS RESULTS	(1) YES	(0) NO	(7) UNK	D	S	(0) NONE	(7) UNK	(N) NORMAL	(B) BY PASS	(C) CLOGGED	(W) N/A
(1) FUEL																
(2) OIL, ENGINE																
(3) OIL, TRANS.(S)																
(4) HYDRAULIC FLUID																
(5) OTHER																

B. LAST ASOAP SAMPLE TAKEN (SPECIFY LABORATORY) LAB:				C. SPECIAL ANALYSIS (SPECIFY LABORATORY) LAB:		
AFFECTED COMPONENT	DATE YR MO DAY	A/C HR	HR SINCE	ITEM	TYPE ANALYSIS	FINDINGS

AIRCRAFT MISHAP CASE NO.				OTHER AIRCRAFT	
YR MO DA	TIME	A/C SERIAL		T/M/S	SERIAL

SAVAE Form 946-1, 1 Feb 72

FIGURE 6. TECHNICAL REPORT OF U.S. ARMY AIRCRAFT MISHAP (REVERSE) (TEARDOWN ANALYSIS)

i. Failure code of primary part

j. EIR control number

k. Events surrounding removal if noted (e.g., excessive vibration)

l. Description of defect

m. Conclusion and recommendations

n. DIR authorization type (i.e., AOAP, EIR)

The number of DIRs reviewed for the components under investigation by authorization type are summarized in Table 5. This data covers the period January 1972 through October 1977.

EQUIPMENT IMPROVEMENT RECOMMENDATIONS (EIRs)

The EIR is currently being reported on DA Form 2407 (see Figure 7). The information contained in the EIR provides the basis for comparison between the series of events surrounding the removal of the component (evident monitoring devices, diagnostic procedures, etc.) and the results of the findings of the analytic teardown from the DIR. All available EIRs that were identified through the Disassembly Inspection Reports were retrieved from TSARCOM. Table 6 identifies the number of EIRs available from existing TSARCOM data files as compared with the number identified on the DIRs. Overall, approximately 57 percent of the number of EIRs identified in the DIRs were available in the TSARCOM files. TSARCOM personnel responsible for the processing of the EIRs gave several possible reasons why a large percentage of the EIRs were not available:

- Human error involved in the handling and processing of the document, both in the field and at the control center.

- Reassignment of the function to different engineering groups with different personnel.

Further discussions with personnel in the EIR control group at TSARCOM indicate that significant effort would be required to track down missing EIRs by reviewing the respective Action Officer's records. A number of these missing records may have already been disposed of, either because the case has been closed or to provide the space for the 300-plus EIRs that are being received weekly into the control center.

TABLE 5. SUMMARY OF THE
NUMBER OF DISASSEMBLY INSPECTION REPORTS (DIRs) REVIEWED BY AUTHORIZATION TYPE

Period Covered - Jan. 1972 - Oct. 1977

A/C Model	Component Nomenclature	Component Part No.	Total DIRs	-----DIR Authorization Type -----			
				EIR	TSARCOM Directive	USAAAVS	AOAP
CH-47B	Engine, T55L7C	2-000-030-22	22	4	1	3	14
CH-47B	Eng. Transmission	114D6001-19	1			1	
CH-47B	Eng. Transmission	114D6001- 20	2		1	1	1
CH-47B	Fwd. Transmission	114D1001-27	2	1			1
CH-47B	Aft. Transmission	114D2200-5	2			1	1
OH-58A	Engine, T63A700	6874201	242	76	36	46	84
OH-58A	Main Transmission	206040003-5	21	3	11	2	5
OH-58A	Tail Rotor Gearbox	206040400-7	7		1	2	4
OH-58A	Tail Rotor Gearbox	206040400-9	2	1			1
CH-47C	Engine, T55L11A	2-001-020-05	22	8	3	5	6
CH-47C	Engine, T55L7C	2-000-030-22	14	4	1	6	3
CH-47C	Eng. Transmission	114D6200-2	1		1		
CH-47C	Eng. Transmission	114D6200-3	3		1	2	
CH-47C	Eng. Transmission	114D6001-20	1			1	
CH-47C	Fwd. Transmission	114D1200-3	2	1		1	
CH-47C	Fwd. Transmission	114D1200-5	1	1			
CH-47C	Fwd. Transmission	114D1200-6	2		1		1
CH-47C	Fwd. Transmission	114D1200-7	1		1		

TABLE 5 (CONT). SUMMARY OF THE
NUMBER OF DISASSEMBLY INSPECTION REPORTS (DIRs) REVIEWED BY AUTHORIZATION TYPE

Period Covered - Jan. 1972 - Oct. 1977

A/C Model	Component Nomenclature	Component Part No.	Total DIRs	-----DIR Authorization Type ----- EIR	TSARCOM Directive	USAAVS	AOAP
CH-47C	Aft Transmission	114D2200-7	3			1	2
CH-47C	Aft Transmission	114D2200-8	2		1	1	
CH-47C	Aft Transmission	114D2200-9	2	1		1	
AH-1G	90° Gearbox	209-040-400-11	12	1		7	4
AH-1G	Main Transmission	204-040-016-5	1	1			
AH-1G	Engine, T53L13B	1-000-060-10	54	10	4	23	17
AH-1G	Engine, T53L13A	1-000-060-08	2	1		1	
AH-1G	Main Transmission	204-040-016-1	1				1
AH-1G	42° Gearbox	204-040-003-37	2		1	1	
UH-1H	Engine, T53L13A	1-000-060-08	8	3		4	1
UH-1H	Engine, T53L13B	1-000-060-10	252	94	13	73	72
UH-1H	90° Gearbox	204-040-012-13	72	8	4	15	45
UH-1H	Transmission	204-040-016-5	14	3		4	7
UH-1H	Transmission	204-040-016-3	2	1		1	
UH-1H	Transmission	204-040-016-1	4			1	3
UH-1H	42° Gearbox	204-040-003-37	19	1	2	9	7

MAINTENANCE REQUEST
For use of this form, see TM 38-750; the proponent agency is Office of the Deputy Chief of Staff for Logistics

*See reverse of file copy for codes and additional data

PAGE NO 1 | NO. OF PAGES 1

REPORTS CONTROL SYMBOL CSGLD 1047 (R1)

SECTION I — ☐ WORK REQUEST ☐ MWO ☐ EIR ☐ ORGANIZATION ISSUE PRIORITY DESIGNATOR CODE

CONTROL NUMBER	1a. ORGANIZATION	b. LOCATION	c. UNIT IDEN CODE
925644			

2. SERIAL NUMBER	3. NOUN NOMENCLATURE	4. LINE NUMBER	5. MODEL	6. FEDERAL STOCK NUMBER

7. STRAC	8. UTILIZATION CODE*	9. SELECTED ITEM	10. HOURS	11. MILES	12. ROUNDS	13. STARTS
☐ 1 YES ☐ 2 NO	☐	☐ 1 YES ☐ 2 NO				

14. FAILURE DETECTED DURING (Select one and ✓ or X): ☐ A SCHEDULED MAINTENANCE ☐ C TEST ☐ E STORAGE ☐ G FLIGHT ☐ B HANDLING ☐ D NORMAL OPERATION ☐ F INSPECTION ☐ H OTHER

15. FIRST INDICATION OF TROUBLE (Select one and ✓ or X): ☒ 088 INOPERATIVE ☐ 258 OVERHEATING ☐ 780 OUT OF ADJUSTMENT ☐ 008 NOISY ☐ 387 LOW PERFORMANCE ☐ OTHER

16. DESCRIBE DEFICIENCIES OR SYMPTOMS ON THE BASIS OF COMPLETE CHECKOUT AND DIAGNOSTIC PROCEDURE IN EQUIPMENT TM (Do not prescribe repairs)

SECTION II · WORK ACCOMPLISHED

17a. REPAIR ORGANIZATION/ACTIVITY	b. UNIT IDEN CODE	18. TYPE ORGANIZATION/ACTIVITY ACCOMPLISHING WORK (Select one and ✓ or X)	19. AMS ACT. CODE
c. LOCATION		☐ 1 TOE ☐ 2 TD ☐ 3 CONTRACTOR	

20a.	b. FAILURE CODE*	c. COMPONENT/PART NOUN, SERVICE, OR MWO NO. — d. CB CODE	e. REFERENCE DESIGNATOR	f. MFR. CODE	g. MANHOURS (Hours & tenths)	h. FEDERAL STOCK NUMBER	i. PART SOURCE CODE	j. QUANTITY	k. PARTS COST
					l. TOTAL MANHOURS	m. TOTAL MANHOURS COST		n. TOTAL PARTS COST	

21. DELAY (Select one and ✓ or X): ☐ 1 PARTS ☐ 2 MANPOWER ☐ 3 FACILITIES ☐ 4 FUNDS ☐ 5 TOOLS

22. ☐ DATA TRANSCRIBED TO LOG BOOK

23. SUBMITTED BY	24. RECEIVED BY	25. WORK STARTED BY	26. INSPECTED BY	27. ACCEPTED BY	28. DISPOSITION (Select one and ✓ or X)
JULIAN DATE	JULIAN DATE	JULIAN DATE	JULIAN DATE	JULIAN DATE	☐ A TO USER ☐ B TO STOCK ☐ C SALVAGED ☐ D EVACUATED ☐ E CANNIBALIZATION

SECTION III · EQUIPMENT IMPROVEMENT RECOMMENDATION

29. NORMAL REPLACEMENT (Select one and ✓ or X)	30. EIR (Select one and ✓ or X)	31. RECOMMENDATION (Select one and ✓ or X)	32a. ORGANIZATION/ACTIVITY	b. UNIT IDEN CODE
☐ 1 YES ☐ 2 NO	☐ E EMERGENCY ☐ U URGENT ☐ R ROUTINE	☐ A IMPROVE DESIGN ☐ B MODIFY ☐ C REVISE PROCEDURE ☐ D OTHER (Specify)	c. LOCATION	d. SUBMITTED BY

33. FEDERAL STOCK NUMBER	34. NOUN NOMENCLATURE	35. OPINION OR REMARKS. DESCRIBE CONDITIONS UNDER WHICH FAILURE OCCURRED. ATTACH PHOTOS OR SKETCHES IF AVAILABLE

DA FORM 1 JAN 64 2407 — CONTROL COPY 3

FIGURE 7. EIR REQUEST, DA FORM 2407

TABLE 6. NUMBER OF EQUIPMENT IMPROVEMENT RECOMMENDATIONS (EIRs) SPECIFIED THROUGH DISASSEMBLY INSPECTION REPORTS (DIRs) AS COMPARED TO EIRs AVAILABLE FOR REVIEW (PERIOD COVERED: JANUARY 72-OCTOBER 77)

Aircraft Model	Component Nomenclature	Component Part Number	No. EIRs Specified from DIR Data	No. EIRs Available
CH-47B	Engine, T55L7C	2-000-030-12	9	6
	Engine Transmission	114D6001-19B	2	1
	Fwd. Transmission	114D1001-27	1	0
CH-47C	Engine, T55L11A	2-001-020-05	12	8
	Engine, T55L7C	2-000-030-22	11	10
	Engine Transmission	114D6200-3	1	0
	Fwd. Transmission	114D1200-3	3	1
	Aft Transmission	114D2200-7	1	1
AH-1G	90° Gearbox	209-040-400-11	3	2
	Main Transmission	204-040-016-5	1	1
	Engine, T53L13B	1-000-060-10	21	11
	Engine, T53L13A	1-000-060-08	1	1
	42° Gearbox*	204-040-003-37	NA	NA
UH-1H	Engine, T53L13A	1-000-060-08	4	2
	Engine, T53L13B	1-000-060-10	137	88
	90° Gearbox	204-040-012-13	28	21
	Main Transmission	204-040-016-5	6	3
	Main Transmission	204-040-016-3	1	1
	Main Transmission	204-040-016-1	1	1
	42° Gearbox*	204-040-003-37	NA	NA
OH-58A	Engine, T63A700	6874201	123	50
	Main Transmission	206-040-003-5	5	3
	Tail Rotor Gearbox	206-040-400-7	1	1
	Tail Rotor Gearbox	206-040-400-9	2	1
		Total	374	213

*/ 42° Gearbox Not Applicable in this analysis portion of report.

The data elements extracted from the available EIRs include:

a. Circumstances prior to difficulty

b. Description of difficulty

c. Cause (as conceived by the aviation unit maintenance personnel)

d. Action taken

e. Recommendations

These data were matched with the respective DIR results to provide a complete picture of the effectiveness of the diagnostic monitoring devices involved or procedures utilized in the removal action.

ACCIDENT/MISHAP REPORTS

A review was made of all accident/mishap reports relevant to the aircraft/component under investigation that have been identified as a definite or suspected material cause factor. These reports covered the period January 1972 through September 1974 and were received from the U.S. Army Agency for Aviation Safety (USAAAVS). They comprise the sanitized output of the Forms 2397-1 (Summary - Figure 8), 2397-3 (Narrative - Figure 9), and the 2397-7 and 7A (Maintenance and Material Data - Figures 10 and 11). The quantity of reports by mishap class for the component under investigation is presented in Table 7.

The primary purpose of incorporating mishap report data into this analysis is to focus upon the status and sequence of diagnostic indication(s) or procedures prior to a material failure-related accident/mishap. The data elements collected from the USAAAVS mishap reports include:

a. Aircraft model

b. Mishap classification

- precautionary landing
- forced landing
- incident
- minor
- major substantial damage
- total loss

```
01/16/78      RIN: A04A      UNITED STATES ARMY AGENCY FOR AVIATION SAFETY, FORT RUCKER, ALABAMA 36360                PAGE NO 00001
---CASE IDENT----                        TECHNICAL REPORT OF U.S. ARMY AIRCRAFT ACCIDENT
  DAT-   SEQ M/AC TIME A/C SN  OTHER SN                 DA2397-1 SUMMARY                          STATUS (FINAL ACCID)
67 34 27  14  1   9483

                         1. CLASS  FORCED LANDING          (5)  2. DATE    /  /  ,LOCAL TIME       3. PER. OF DAY  DAY  (2)

4. LOCATION                    ( )    5.                          ( )    6. NEAREST MILITARY INSTALLATION
                   (  )                                                          N.M.        DIRECTION

7.   .             (  ) 9. ACFT  TMS:  UH 1H ------------------ORGANIZATION AIRCRAFT ASSIGNED-------------------------
                   (  )  SER/NUMBER:          MAJOR COMMAND:
                   (  )                                    UIC:

8. NO. ACFT. INV.  (1)          INSTALLATION AIRCRAFT ASSIGNED

10. ESTIMATED COST OF DAMAGE  AIRCRAFT DAMAGE COST                $0  OWNERSHIP
                              AIRCRAFT REPAIR MAN HOURS             0
                              OTHER DAMAGE MIL.                   $0  OWNERSHIP
                              OTHER DAMAGE                        $0  OWNERSHIP
                              TOTAL COST                          $0

11. SURV  NOT APPLICABLE      (5)          15. FUEL AND OIL  LB/FU QT/OIL          16. FLAMMABLE FLUID SPILLAGE
                                               TAKEOFF       01400   010                AIRCRAFT SYS.            CARGO
12. INFLIGHT ESCAPE  NOT APPLICABLE    (0)     EMERGENCY     01000   010             NONE          (0)    NONE         (0)
                                               EVENT         01000   010                           ( )                 ( )
13. FIRE  NONE       (0)                                                                           ( )                 ( )
                                                                                                   ( )                 ( )
14. POSTCRASH ESCAPE  NOT APPLICABLE  (0)                                                          ( )                 ( )

17.            PERSONNEL INVOLVED                 PERSONNEL INJURED                18. TERR. CRASH SITE
    OCC-MIL NON-OCC   OCC   NON-OCC           MIM  MIN  MAJ  FAT  MIS          SLOPE             (07)
             MIL   NON-MIL NON-MIL             0    )    0    0    0           ROLLING           (11)
         .     0        )       0                                                                ( )
                                                                                                 ( )
                                                                                                 ( )

20. CLEARANCE  VFR LOCAL            (A)   22. FLIGHT DATA  ALT.         HEAD.  PHASE    AIRCRAFT  FLIGHT    DENSITY    OVER
                                                           MSL.  KTS.   COMP.  OPER.    WEIGHT    DURATION  ALTITUDE   GROSS
21. MISSION  SERVICE  (2)                    A. PLANNED    04000  100    250              00000     0050      00000     NO  (0)
                                    ( )  B. EMERGENCY     04000  100    250   6C         00000     0045      00000     NO  (0)
                                    ( )  C. TERMINATION   00000  000    280   7BE1       00000     0045      00000     NO  (0)

23. CAUSE RELATED FACTORS  A. PERSONNEL  DUTY       B. ENVIRONMENTAL          C. MATERIEL          D. WEATHER   ( )
                           FLIGHT CREW       ( )       AIRFIELD       ( )   FAILURE/
                                             ( )       SERVICES       ( )   MALFUNCTION (0)
                                             ( )       COMMAND        ( )                           MAINTENANCE (S)
                           GROUND CREW  MEP  (S)       TRAINING       ( )    DESIGN       ( )  Y. OTHER CODE( )
                                             ( )       OTHER          ( )    OTHER        ( )  Z. UNDETERMINED ( )
                           SUPERVISOR        ( )
                           OTHER             ( )
TYPE

FOR ACCIDENT PREVENTION PURPOSES ONLY, PROHIBITED FOR USE FOR PUNITIVE PURPOSES OR MATTERS OF LIABILITY, LITIGATION, OR COMPETITION
```

FIGURE 8. EXAMPLE OF DA2397-1, SUMMARY OUTPUT

```
01/16/78      RIN: A04A      UNITED STATES ARMY AGENCY FOR AVIATION SAFETY, FORT RUCKER, ALABAMA 36360                PAGE NO 00002
---CASE IDENT----                          TECHNICAL REPORT OF U.S. ARMY AIRCRAFT ACCIDENT
  DATE   SEQ M/AC TIME A/C SN  OTHER SN                    D2397-3 NARRATIVE
67 34 27  14  1    9483                                                                  STATUS (FINAL ACCID)

    1.  NARRATIVE
                 PILOT WAS UNABLE TO MAINTAIN DIRECTIONAL CONTROL DUE TO FAILURE OF T/R DRIVE, SEVERE VIBRATIONS WERE
                  EXPERIENCED.  A/C WAS AUTOROTATED TO AN OPEN FIELD.
                 INTERNAL FAILURE OF 4- GEAR BOX, RESULTING IN LOSS OF POWER TO T/R.
                 SUPPLEMENT:  THE OUTPUT COUPLING OF THE 42 DEGREE GEARBOX FAILED DUE TO BREAKDOWN OF LUBRICANT.  SUS
                 PECT WRONG LUBRICANT WAS USED WHEN THIS COUPLING WAS PACKED DURING OVERHAUL.

FOR ACCIDENT PREVENTION PURPOSES ONLY, PROHIBITED FOR USE FOR PUNITIVE PURPOSES OR MATTERS OF LIABILITY, LITIGATION, OR COMPETITION
```

FIGURE 9. EXAMPLE OF DA2397-3, NARRATIVE OUTPUT

```
01/16/78     RIN: A04A     UNITED STATES ARMY AGENCY FOR AVIATION SAFETY, FORT RUCKER, ALABAMA 36360               PAGE NO 00003
---CASE IDENT----                             TECHNICAL REPORT OF U.S. ARMY AIRCRAFT ACCIDENT
  DATE   SEQ M/AC TIME A/C SN  OTHER SN        DA2397-7 - MAINTENANCE AND MATERIEL DATA
67 34 27  14  1    9483                                                                        STATUS (FINAL ACCID)

2. ROLE IN THIS ACCIDENT                          3. WARNING SYSTEM AND INDICATION OF FAILURE/MALFUNCTION
  A. FACTORS        (PRIMARY/SECONDARY)             A. STATUS OF AIRCRAFT WARNING SYSTEMS   C. INDICATIONS OF FAILURE/MALFUNCTION
    1. MAINTENANCE  SUSPECTED PRIMARY      (2)          UNDETERMINED                  (9)   SEQUENCE  DESCRIPTION             CODE
    2. MATERIEL     DEFINITE SECONDARY     (3)                                                1.    VIBRATION                  (01)
    3. PUBLICATIONS NONE                   (0)                                                2.    UNUSUAL NOISE              (02)
    4. POL          NONE                   (0)                                                3.    UNUSUAL ATTITUDE           (03)
                                                                                              4.                               ( )
                                                                                              5.                               ( )

4. ENGINE OPERATING INDICATIONS
  A. LOCATION/SERIAL NO.      B. TORQUE  C. RPM(N1)  D. RPM(N2)  E. TEMP  F. OIL TEMP  G. OIL PRESS


5. TRANSMISSION/GEARBOX OPERATING INDICATIONS
  A. NOMENCLATURE          SERIAL NUMBER        B. OIL TEMP   C. OIL PRESS  D. ROTOR RPM  E. OVERSPEED/CODE  F. OVERTORQUE/CODE.
     42 G/B                SN813577                                                          NO      (0)          NO     (0)
                                                                                                     ( )                 ( )

    TYPE/MODEL/SERIES     UH 1H

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FIGURE 10. EXAMPLE OF DA2397-7, MAINTENANCE AND MATERIEL DATA OUTPUT

```
01/16/78      RIN: A04A      UNITED STATES ARMY AGENCY FOR AVIATION SAFETY, FORT RUCKER, ALABAMA 36360                PAGE NO 00004
                                    TECHNICAL REPORT OF U.S. ARMY AIRCRAFT ACCIDENT
 ---CASE IDENT----
  DATE   SEQ M/AC TIME A/C SN  OTHER     2397-7A MAINTENANCE AND MATERIAL DATA (CONTINUED)              STATUS (FINAL ACCID)
 67 34 27  14  1    9483

7. FAILED OR MALFUNCTIONED MATERIAL   (DID PART NO. MATCH THAT LISTED IN TM? YES      (1))

                                  A. MAJOR COMPONENT                                 D. PART
 IDENT/HISTORICAL DATA:            ROTOR & TRANSMISSION                               42DEG GEAR BOX
   1. NOMENCLATURE
   2. TYPE/MODEL/SERIES                                                               20404000337
   3. PART NUMBER                                                                     1615009182676
   4. FEDERAL STOCK NUMBER                                                            97499
   5. MFG. CODE
   6. TM DATA:                                                                                              (        )
     C. FUNCTIONAL GROUP                                                              813557
   7. SERIAL NUMBER
   8. TAMMS DATA:                                                                     2
     A. NO. OVERHAULS                                                                  287
     B. HR. SINCE OVERHAUL                                                             496
     C. HR. SINCE NEW
     D. HR. SINCE LAST INSTALL.                                (      )                                (      )
     E. LAST OVERHAUL FACILITY
     F. DATE OF LAST OVERHAUL      000000
   9. LAST SPECIAL INSPECTION
     A. TYPE                                                                          000000
     B. DATE                     000000                                               000
     C. HOURS SINCE              000                                                              (     )
  10. TYPE FAILURE               (    )
  11. CAUSE OF FAILURE           (    )
  12. EIR CONTROL NUMBER         (        )
 8. ANALYSIS:
   D. TEARDOWN ANALYSIS REQUEST: WAS TEARDOWN ANALYSIS REQUESTED?      ( )
       USAAAVS/THEATRE CONTROL NUMBER  72-14

         SOURCE (A)

   TYPE/MODEL/SERIES:   UH 1H             SHEET NO 01

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FIGURE 11. EXAMPLE OF DA2397-7A, MAINTENANCE AND MATERIEL DATA OUTPUT (CONTINUED)

TABLE 7. NUMBER OF ACCIDENT/MISHAP REPORTS REVIEWED BY MISHAP CLASSIFICATION FOR PERIOD 1 January 1972-30 September 1974

Model	Component Nomenclature	Total Mishap	Precaut. Landing	Forced Landing	Incident	Minor	Major Substantial	Total Loss
OH-58A	T/R Gearbox	8	6		1		1	
	Main XMSN	24	24					
	Engine	288	155	105	10		10	8
CH-47C	Engine XMSN	34	34					
	Engine	3	2	1				
	Aft XMSN	7	7					
CH-47B	Engine	9	9					
	Engine XMSN	2	2					
	Fwd XMSN	2	2					
AH-1G	Engine	84	60	12	2	1	6	3
	90° Gearbox	5	3		1		1	
	Main XMSN	1	1					
UH-1H	90° Gearbox	42	40	1			1	
	Main XMSN	8	8					
	Engine	449	313	89	7	1	23	16
	42° Gearbox	11	10	1				

c. Estimated cost of damage (includes spare parts and man-hours)

d. Role of maintenance and material failure in accident

- primary definite
- secondary definite
- primary suspected
- secondary suspected

e. Status of on-board warning systems

- operative, proper indication
- operative, faulty indication
- operative, no indication
- inoperative
- undetermined

f. Indication of failure/malfunction (This entry reflects the warning indication received by the aircraft crew of the failure/malfunction of the component. Up to 5 warning indications may be entered, with each showing the sequence in which it was received.) Possible indications are:

- None
- Vibration
- Unusual noise
- Unusual attitude
- Faulty operation
- Odor
- Fluid leakage
- Smoke or fire
- Other personnel
- Master warning light
- Annunciator panel
- Voice warning
- Fire warning light
- Warning horn
- RPM warning light/audio
- RPM warning instrument
- Engine chip detector
- XMSN chip detector
- Gearbox chip detector
- Fuel
- Oil
- Hydraulics

g. Major component that failed

h. Part name and number of major component

i. Teardown requested (Yes or No)

REVIEW OF HISTORICAL RECORDS AND MAINTENANCE PERSONNEL INTERVIEWS

Aircraft historical records maintained by several aviation units of the 101st Airborne Division (Air Mobile) located at Fort Campbell, Kentucky, were reviewed. Interviews were conducted with company and group level maintenance, maintenance technical inspector/quality control, and maintenance management personnel, as well as with TSARCOM support personnel, as an adjunct to the aircraft historical record review.

The primary objective of this review/interview program was to identify the means by which operating units arrive at a decision to remove a major dynamic component without specific higher authority directive to do so prior to reaching the established component TBO. The review procedure encompassed three steps:

1. Review of the DA Form 2408-5, the DA Form 2410 log which provided a convenient record of all DA Form 2410 component removals. All components of interest are DA Form 2410 items.

2. Extraction of premature removals, excepting cannibalization.

3. Referral to the DA Forms 2408-13 or 14 or the DA Form 2404 write-up(s) which preceded the removal decision.

Step 3 of the records review procedure was combined with the interview process at the operating unit level to positively identify the diagnostic devices, procedures, or techniques that led to the actual removal decision. Emphasis was given to correlation between the failure code as documented on the removed component DA Form 2410 versus the reconstruction of the removal event decision.

The findings from this review of historical records and related interviews are:

1. The Table 3 breakdown of removal codes as a basis for determining failure rates versus overall removal rates is a valid approach.

The failure codes used by all the operating units visited, as recorded on the DA Form 2410, are arrived at following an attempt to accurately describe the condition of the failed/degraded component. The condition is sometimes overstated, but the breakdown between the category 1-6 (failure) versus category 7-13 (other than failure) appears valid.

2. Institutional memory on the part of the aircraft operator is a primary basis for diagnosis, with instrument readings, vibration, heat, noise, and scheduled inspections being the primary initial indicators eventually leading to removal. This institutional memory has several forms. For example, the engine Health Indication Test (HIT) check serves as a trend analysis with nonacceptable parameter ranges, instrument readings are in the green or exceed the normal reading, components run hotter than normal, pressures are above or below normal, vibration levels are above normal, etc. While specific skills may be involved in interpreting such signs or indications, each of the operating units visited appeared to be fully capable of accomplishing such interpretation based on their historical records.

3. The premature removal of a major dynamic component is not a trivial matter, and a variety of talents are involved in each decision, including the person first complaining about the time, the technical inspector(s), the maintenance officers, and frequently the TSARCOM technical representative. It must be noted that supply availability does play a role; that is, a readily available spare might be utilized to resolve a "maybe it should be"/"maybe it shouldn't be" removal decision.

4. A vibration test kit, just now coming into use within the 101st Airborne Division (Airmobile), provides a significant increase in aircraft operator diagnostic capability. Vibration is one of the most difficult malfunctions to address and isolate. The kit permits rapid blade track and dynamic balance to be accomplished; and if vibration cannot be brought within acceptable tolerance through the use of the kit, then another more basic problem does exist. The kit has been used by 'B' Company of the 158th Aviation Battalion. They obtained their kit in late spring of 1977, and are still in the application/learning stage of use. The kit is routinely used in conjunction with each phase or periodic inspection test flight,

prior to releasing the aircraft back for routine operational use. Also, the equipment is used for flight line evaluation of vibration gripes.

Intensive and continuous training is required in order to obtain maximum benefit from the vibration test kit equipment. Benefits which can be realized include:

- More time available for operational flying due to reduced maintenance hours needed for tracking and vibration reduction.

- Reduced removal of components failing due to high vibration levels because of lower vibration levels attainable through using the vibration test kit to isolate/eliminate vibration.

These advantages are already being realized by 'B' of the 158th Aviation Battalion and are anticipated by the 2/17 Cavalry which received its vibration test kit in October 1977 and is already experiencing positive results in vibration reduction. Both 'B' Company 158th Aviation Battalion and the 2/17 Cavalry are beginning to explore the potential for fault isolation/troubleshooting. Hands-on training is emphasized as being necessary for obtaining the benefit that is potentially inherent in the field use of the vibration test kit equipment.

IV. DISCUSSION OF METHODOLOGY

COMPONENT COMBINATIONS AND ELIMINATIONS

After review and assessment of the available data, information for similar components and for the same components on different aircraft was combined. This provided larger samples of both the MIRF and DIR data bases for a given component, and hence a greater confidence in the analysis results. Also, because some of the initial components that were reviewed lack sufficient DIR and/or MIRF data to provide the parameters required, these were eliminated from further evaluation.

Table 8 presents the process of combinations and eliminations of the initial components under investigation to the final components on which an analysis of diagnostic effectiveness was performed.

DEVELOPMENT OF THE CURRENT DA FORM 2410 COMPONENT FAILURE CHARACTERISTICS

After classifying the DA Form 2410 removal codes into the 13 removal categories, the respective removals per flight-hour interval were entered onto a format as shown in Table 9. Although the analysis focussed upon categories 1-6 (removals due to failure) it was necessary that all 13 categories be examined to identify any removals in categories 7-13 that would have been initially classified as failures (1-6) had adequate diagnostics been available. This information was gathered on both the new and overhaul components of the type identified in Table 8. The failure characteristics developed from the current DA Form 2410 were therefore based on the composite of categories 1-6 as identified from the MIRF reports, and are representative of the current field removal experience.

DEVELOPMENT OF THE "PSEUDO"-DA FORM 2410 COMPONENT FAILURE CHARACTERISTICS

The pseudo-DA Form 2410 was developed to display what could

TABLE 8. COMPONENTS THAT WERE COMBINED TO PROVIDE LARGER SAMPLES AND ELIMINATED DUE TO DATA VOIDS

Model	Initial Components: Nomenclature	Initial Components: Part Number	Final Components
UH-1H	Engine, T53L13	1-000-060-03	Eliminated-No DIR Data
	Engine, T53L13A	1-000-060-08	Combined
	Engine, T53L13B	1-000-060-10	
	Main XMSN	204-040-001-17	Eliminated-No DIR Data
	Main XMSN	204-040-016-1	Combined
		204-040-016-3	
		204-040-016-5	
	90° Gearbox	204-040-012-13	No Change
	42° Gearbox	204-040-003-37	Combined
AH-1G	Engine, T53L13	1-000-060-03	Eliminated-No DIR Data
	Engine, T53L13A	1-000-060-08	Combined
	Engine, T53L13B	1-000-060-10	
	Main XMSN	204-040-009-65	Eliminated-No DIR Data
	Main XMSN	204-040-016-1	
	Main XMSN	204-040-016-5	
	90° Gearbox	209-040-400-11	No Change
	42° Gearbox	204-040-003-37	
OH-58A	Engine, T63A700	6874201	No Change
	Main XMSN	206-040-003-5	No Change
	T/R Gearbox	206-040-400-7	Combined
	T/R Gearbox	206-040-400-9	

TABLE 8 (Cont).

Model	Initial Components: Nomenclature	Part Number	Final Components
CH-47B	Engine, T55L7C	2-000-030-22	Combined
	Engine, XMSN	114D6001-19/20	Eliminated; insufficient DIR Data
	Fwd XMSN	114D1200-3	Eliminated-No DIR Data
	Aft XMSN	114D2001-26	Eliminated-No DIR Data
	Fwd XMSN	114D1001-27	Eliminated; insufficient MIRF Data
CH-47C	Engine, T55L7C	2-000-030-22	Combined
	Engine, T55L11	2-001-020-01	Eliminated-No DIR Data
	Engine, T55L11A	2-001-020-05	Eliminated; insufficient *DIR Data*
	Engine XMSN	114D6200-2	Combined
	Engine XMSN	114D6200-3	Combined
	Engine XMSN	114D6200-1	Eliminated-No DIR Data
	Engine XMSN	114D6001-20	Eliminated; insufficient MIRF Data
	Fwd XMSN	114D1200-3	
	Fwd XMSN	114D1200-5	Eliminated; insufficient DIR Data
	Fwd XMSN	114D1200-6	Eliminated; insufficient MIRF Data
	Fwd XMSN	114D1200-7	Eliminated; insufficient MIRF Data
	Aft XMSN	114D2200-5	Eliminated-No DIR Data
	Aft XMSN	114D2200-7	Eliminated; insufficient DIR Data
	Aft XMSN	114D2200-8	Eliminated; insufficient MIRF Data
	Aft XMSN	114D2200-9	Eliminated; insufficient MIRF Data

TABLE 9. FORMAT USED TO CLASSIFY DA FORM 2410 REMOVALS

A/C Model:__________ Nomenclature:__________ P/N:__________ Data Type:__________

Removal Mode Classification	Removal During Flight Hour Intervals																
	0-99	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1199	1200-1299	1300-1399	1400-1499	1500-1599	1600-1699
01-Quality Control																	
02-Observation																	
03-Measurement																	
04-Diagnostic Instruments																	
05-Seals, Leaks																	
06-Failure																	
07-Maintenance Induced																	
08-Environment																	
09-Crash, Battle, Accidents																	
10-Operations																	
11-Other																	
12-Scheduled Maintenance																	
13-Supply Convenience																	
TOTAL																	

have been expected if the disassembly inspection capabilities of Aviation Intermediate Maintenance (AVIM) or Depot levels were at the AVUM level. As a result of the analytic teardown, the initial reason for removal may be reclassified to present the exact condition of the component. In many cases, components were removed prematurely and upon teardown no defects were noted. If DIR capability (or optimum diagnostics) had been available, then these components could have remained in service, thus increasing the mean life of that component.

Also, the pseudo-DA Form 2410 reflects the omission of any externally induced removals from the current DA Form 2410 category 1-6 failure characteristics. If the DIR did reclassify the removal from a failure (class 1-6) to a maintenance induced removal (class 7), then it was assumed that the DIR capability at AVUM would have allowed that component to remain in service.

From the DIRs available by component, the DA Form 2410 (field) removal code and the reason for failure as determined in the tear-down were classified into the 13 removal categories. This information then provided the basis from which the matrix in Table 10 was developed. The flight hours attendant to the removal action were recorded in the matrix to provide a basis for determination of the life characteristic parameters required. If the initial removal from the field was classified, say, as an 04 (Diagnostic Instruments) and the DIR found no defects, then this removal would be classified under the 7-13 (nonfailure) category column in the appropriate flight-hour interval and in Row 04.

Once all available DIR data was entered into the matrix, then the pseudo-DA Form 2410 could be developed. The assumption was made that the redistribution of the DA Form 2410 data where DIRs were available would be the same for these DA Form 2410 events when the DIRs were not available. Thus if, for each category/flight-hour interval on the left side of the matrix (current 2410 classifications), a determination of the reclassification categories were made on a percentage basis, this distribution would be applicable to all other removals in the same category. An example of the reclassification based on the DIRs is shown as follows:

TABLE 10. MATRIX TO DETERMINE RECLASSIFICATION OF REMOVAL CATEGORIES FOR THE PSEUDO DA FORM 2410

DA Form 2410 Removal Categories / DIR Class	Class 01 Flight Hour Intervals						Class 02 Flight Hour Intervals						Classes 03-13
	100	200	300	400	500	600	100	200	300	400	500	600	
01													
02													
03													
04													
05													
06													
13													

Flight-Hour Interval	Total DA Form 2410 Reported Removals with DIRs	Breakdown of DIR Reclassifications	% of Total
0-100	10	2 went to Class 03 1 went to Class 05 2 went to Class 06 5 went to Classes 7-13	20 10 20 50

Utilizing the percentages of the total being reclassified, the original DA Form 2410 class/flight interval value was redistributed. If going back to the original DA Form 2410 we find that a total of 20 removals were in category 4, 0-100 flight-hour interval, then these 20 would be reclassified into a pseudo-DA Form 2410 as follows:

20% or 4 would go to class 03 (0-100)
10% or 2 would go to class 05 (0-100)
20% or 4 would go to class 06 (0-100)
50% or 10 would go to classes 7-13 (0-100)

Note that the removals going to classes 7-13 now leave the failure categories, and therefore could have remained in service. This process was continued until the pseudo-DA Form 2410 was complete for all DIR data available on that component.

The resulting values of the failure categories (class 1-6) for both the current DA Form 2410 and the pseudo-DA Form 2410 were then entered onto the format shown in Table 11. This comparison of the removal distributions provided a means for quick determination of which failure classifications present the greatest potential for a change in diagnostic capability. The summation of the removals by flight interval also provided an indication of the number of premature removals that had been assessed as failures on the basis of the current diagnostic devices/techniques. It was next necessary to redistribute these premature removals forward over time to the flight-hours at which they would be expected to be removed if AVUM had full diagnostic capability. A statistical procedure was developed to provide an estimate of this additional time that the premature removals would have remained in service. This procedure is described in the following paragraphs.

TABLE 11. FORMAT USED TO COMPARE THE FIELD DA FORM 2410 FAILURE REMOVAL DISTRIBUTION WITH THE PSEUDO FAILURE REMOVAL DISTRIBUTION

A/C Model:__________ Nomenclature:__________ P/N:__________ Data Type:__________

Removal Mode Classification	0-99	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1199	1200-1299	1300-1399	1400-1499	1500-1599	1600-1699
01-Quality Control																	
02-Observation																	
03-Measurement																	
04-Diagnostic Instruments																	
05-Seals, Leaks																	
06-Failure																	

PSEUDO-DA FORM 2410 REMOVAL DISTRIBUTION

Removal Mode Classification	0-99	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099	1100-1199	1200-1299	1300-1399	1400-1499	1500-1599	1600-1699
01-Quality Control																	
02-Observation																	
03-Measurement																	
04-Diagnostic Instruments																	
05-Seals, Leaks																	
06-Failure																	

ALGORITHM FOR REDISTRIBUTION OF COMPONENT LIFE CHARACTERISTICS BASED ON DIR REVIEW

A DIR either confirms or contradicts an AVUM finding of failure. Where it contradicts, it becomes of interest to determine how much life was abbreviated through improper diagnosis. This section sets forth the mathematics to estimate the improvement in equipment service life that would have occurred if DIR diagnostic capability had been provided at the Aviation Unit Maintenance Level.

From the DA Form 2410 generated by AVUM, we have $n_j (j=1,2,\ldots\nu)$, the number of equipment removals for "failure" in the j^{th} 100 flight-hour interval. From the DIRs conducted on equipments falling into the i^{th} interval because they were designated as "failure" by AVUM, a certain proportion, say p_j, were found to be free of defect. Thus, the number of valid removals in the j^{th} interval is given by $n_j(1-p_j)$. Assuming that the proportion p_j were returned to service, it is necessary to coordinate the extra life that would be experienced. This extra life thus becomes a measure or baseline upon which to measure effectiveness of diagnostic devices, procedures, and techniques.

Let f_j equal the fraction of equipments removed by AVUM in the i^{th} flight-hour interval; viz,

$$f_j = \frac{n_j}{\sum_{j=1}^{\nu} n_j} = \frac{n_j}{n} \qquad \text{and}$$

$$R_j = \frac{\sum_{i=j}^{\nu} n_i}{n}$$

equal the fraction of equipments which are not removed by AVUM prior to 100j flight-hours (the fraction of equipments which survive the j^{th} interval).

With the above definitions, we are now in position to estimate the influence which DIR capability at the AVUM level would have on the distribution of flight-hours to removal. Given that an equipment has survived the i^{th} interval, it follows by definition that

$$\frac{f_j}{R_i}$$

is an estimate of the probability that the equipment would be removed by AVUM for "failure" in the j^{th} interval, $i \leq j \leq \nu$. Since $p_i n_i$ is the number of AVUM "failures" found free of defect by the DIR in the i^{th} interval, we can redistribute them in accordance with

$$\frac{f_j}{R_j} \qquad j = i+1, i+2, \ldots, .$$

Likewise for those in the $(i+1)^{th}$ interval found free of defect by DIR, i.e., $p_{i+1}\, n_{i+1}$, we redistribute them in accordance with

$$\frac{f_j}{R_{i+1}}$$

Continuing in this manner, the number of DIR failure contradictions in the intervals prior to the j^{th} interval will sum to

$$\sum_{i=1}^{j-1} \frac{f_j n_i p_i}{R_i}$$

for reentry into the failure distribution by AVUM in the j^{th} interval. The AVUM "failures" contradicted by DIRs are subtracted from removals in the j^{th} interval. Thus, on the redistribution of failures brought about by DIR review we have, say, m_j as an estimate of the number of failures in the j^{th} interval.

$$m_j = n_j\,(1-p_j) + f_j \sum_{i=1}^{j-1} \frac{n_i p_i}{R_i}$$

The pseudo-DA Form 2410s developed through the above algorithm, as well as the routine DA Form 2410 data, were plotted on Weibull paper to obtain estimates of the Weibull A (scale) and B (shape) parameters; from the A and B values, estimates of

component mean life (μ) and the probability of surviving one-half the mean life $P(\mu/2)$ were determined using the AMSEC data transducer algorithm. Appendix B provides the Weibull plots for both the current and pseudo-DA Form 2410 distributions of the components evaluated in the analysis.

APPLICATION OF THE ANALYTICAL METHODOLOGY FOR SYSTEM EVALUATION AND CONTROL (AMSEC)

The steady-state version of AMSEC was utilized in this analysis on the assumption that the aircraft/components under investigation are those which have been in the Army inventory for some time. The AMSEC methodology provided, for both the current and the pseudo-DA Form 2410s (i.e., for existing and for "perfect" diagnostics at AVUM), the component reliability, availability, and life cycle support cost. It thus made possible a direct, quantitative evaluation of the potential for improvement of the current diagnostic techniques and procedures.

A breakdown of the required input for the steady-state version of AMSEC by aircraft/component is provided in Table 12. The basic inputs that defined the life characteristics of the component, μ and $P(\mu/2)$, are provided for both the current and pseudo-DA Form 2410 calendar hours and man-hours for component replacement, along with material replacement/overhaul costs, are also provided as direct inputs into AMSEC. These estimates were determined from and were assumed to be the same for both the current and pseudo-DA Form 2410 AMSEC analyses. Cost per man-hour for maintenance on all components was input at $15 per hour. A mission duration of 1.8 hours was assumed, along with equipment service time of 6480 hours based upon the present average utilization of approximately 27 hours/month for 20 years of service.

It should be noted that the only cost associated with component failure was the direct operating and support cost (component replacement/overhaul cost and man-hour cost for replacement). The AMSEC will also deal with other costs of failure, such as those associated with loss of life or equipment or a lost mission. This analysis could be readily expanded to include these costs if the Army wishes to place a value on them.

The results of the AMSEC analysis, in the form of a direct comparison of the R/A/C differences, or "deltas" for current and improved diagnostics, are presented in the next section.

TABLE 12. INPUTS INTO STEADY STATE AMSEC FOR DIAGNOSTIC ANALYSES

A/C Model	Component/Part No.	New or Ovhl	TBO Int.	Life Characteristics Current μ	Current $P(\mu/2)$	Pseudo μ	Pseudo $P(\mu/2)$	Calendar Hours to Replace	Man-Hours to Replace	Material Replacement Cost	Cost per Man-Hour
UH-1H	Engine, T53L13A/B (1-000-060-08-10)	New	1800	532	.783	552	.769	5.9	14.8	$142,600	$15.00
UH-1H	Engine, T53L13A/B (1-000-060-08-10)	Ovhl	1800	391	.710	452	.698	5.9	14.8	13,270	15.00
UH-1H	Main Transmission (204-040-016-1/-3/-5)	Ovhl	1500	431	.724	486	.688	10.5	26.3	4,140	15.00
UH-1H	90° Gearbox (204-040-012-13)	New	1200	478	.808	517	.778	4.1	5.7	1,538	15.00
UH-1H	90° Gearbox (204-040-012-13)	Ovhl	1200	371	.752	476	.744	4.1	5.7	421	15.00
AH-1G/ UH-1H	42° Gearbox (204-040-003-37)	New	1500	596	.742	625	.736	2.0	3.7	1,144	15.00
AH-1G/ UH-1H	42° Gearbox (204-040-003-37)	Ovhl	1500	451	.705	474	.693	2.0	3.7	385	15.00
AH-1G	Engine, T53L13A/B (1-000-060-08/-10)	New	1800	482	.788	493	.774	8.4	26.5	142,600	15.00
AH-1G	Engine, T52L13A/B (1-000-060-08/-10)	Ovhl	1800	310	.719	343	.696	8.4	26.5	13,270	15.00
AH-1G	90° Gearbox (209-040-400-11)	New	1100	260	.696	282	.691	4.23	5.70	1,952	15.00
OH-58A	Engine, T63A700 (6874201)	New	750	380	.809	413	.791	11.4	21.3	34,883	15.00
OH-58A	Engine, T63A700 (6874201)	Ovhl	750	293	.776	362	.778	11.4	21.3	11,951	15.00
OH-58A	Main Transmission (206-040-003-5)	New	2000	473	.742	560	.746	8.1	14.3	7,731	15.00
OH-58A	Tail/Rotor Gearbox (206-040-400-7/-9)	New	1200	427	.776	447	.776	4.6	6.6	1,350	15.00
CH-47B/ C	Engine, T55L7C (2-000-030-22)	Ovhl	1800	259	.629	350	.607	4.0	11.0	23,200	15.00
CH-47B/ C	Engine Transmission (114D6200-2/-3)	New	900	282	.693	303	.681	3.5	7.0	15,000	15.00

V. CONCLUSIONS AND RECOMMENDATIONS

POTENTIAL FOR R/A/C IMPROVEMENT THROUGH IMPROVED DIAGNOSTICS

Table 13 is a composite display of the results of the two sets of AMSEC computer runs. As described in the preceding section, an AMSEC analysis was made of each of the components under investigation for each of two cases:

1. The current field diagnostic techniques and procedures were assumed applicable, so that the life/removal characteristics of the components represented current, de facto removal history.

2. An improved field diagnostic capability was assumed to be operative, with an effectiveness corresponding to the DIR capability, so that the life/removal characteristics of the components represented the removal history that would be expected under near-perfect diagnostics.

When input data were available, the AMSEC runs were made on both new and (singly) overhauled versions of each component.

Table 13 displays, for each component, the AMSEC-projected Mean-Time-Between-Unscheduled-Removals (MTBUR); the component reliability for a 1.8-hour mission; the component availability; the spares requirements over its operating life; and the direct operating and support cost in dollars per flight hour over the operating life. For convenience in comparing the costs and the MTBUR, two additional columns are provided showing the percent improvement in using the DIR removal criteria.

It will be noted that all components examined show a net improvement in both life-cycle costs and MTBUR. Where data on both new and overhauled items are available, the relative improvement is greater for the overhauled version. The greatest

TABLE 13. RESULTS OF AMSEC METHODOLOGY

A/C Model	Component/Part No.	New or Ovhl	TBO Int.	Mean-Time-Between-Unscheduled-Removals (MTBUR) Curr.	Pseudo	System Reliability (1.8-hr Mission) Curr.	Pseudo	Availability Curr.	Pseudo	Direct Operating & Supp. Cost/Flight Hour Curr.	Pseudo	Spares Required Curr.	Pseudo	Δ % Cost Savings	Δ % MTBUR
UH-1H	Engine, T53L13A/B (1-000-060-08/-10)	New	1800	531.9	551.5	.9966	.9977	.9890	.9894	$268.51	$258.97	65.86	65.99	- 3.6	+ 3.7
UH-1H	Engine, T53L13A/B (1-000-060-08/-10)	Ovhl	1800	390.9	451.1	.9954	.9960	.9851	.9871	35.52	29.91	68.59	68.27	-15.8	+15.4
UH-1H	Main Transmission (204-040-016-1/-3/-5)	Ovhl	1500	430.0	479.7	.9958	.9963	.9762	.9786	10.55	9.45	67.69	68.27	-10.4	+11.6
UH-1H	90° Gearbox (204-040-012-13)	New	1200	476.7	511.3	.9963	.9966	.9915	.9920	3.41	3.18	65.71	65.98	-6.7	+ 7.3
UH-1H	90° Gearbox (204-040-012-13)	Ovhl	1200	370.3	469.8	.9952	.9963	.9891	.9913	1.37	1.08	67.56	66.83	-21.2	+26.9
AH-1G/ UH-1H	42° Gearbox (204-040-003-37)	New	1500	587.8	612.6	.9970	.9972	.9966	.9967	2.04	1.96	66.27	66.27	- 3.9	+ 4.2
AH-1G/ UH-1H	42° Gearbox (204-040-003-37)	Ovhl	1500	448.4	469.1	.9960	.9962	.9956	.9958	0.98	0.94	68.06	68.22	- 4.1	+ 4.6
AH-1G	Engine, T53L13A/B (1-000-060-08/-10)	New	1800	482.0	492.9	.9963	.9963	.9829	.9832	296.67	290.11	65.97	66.15	- 2.2	+ 2.3
AH-1G	Engine, T53L13A/B (1-000-060-08/-10)	Ovhl	1800	310.0	343.0	.9942	.9947	.9736	.9761	44.09	39.85	69.67	69.90	- 9.6	+10.6
AH-1G	90° Gearbox (209-040-400-1)	New	1100	259.7	281.2	.9931	.9936	.9840	.9852	7.85	7.25	72.20	71.70	- 7.6	+ 8.3
OH-58A	Engine, T63A700 (6874201)	New	750	373.5	398.3	.9954	.9959	.9704	.9722	94.25	88.38	66.19	66.29	- 6.2	+ 6.6
OH-58A	Engine, T63A700 (6874201)	Ovhl	750	291.3	354.1	.9939	.9952	.9623	.9688	42.12	34.65	68.00	66.98	-17.7	+21.6
OH-58A	Main Transmission (206-040-003-5)	New	2000	472.9	559.5	.9962	.9968	.9832	.9857	16.80	14.20	66.89	66.34	-15.5	+18.3
OH-58A	Tail/Rotor Gearbox (206-040-400-7/-9)	New	1200	425.8	445.2	.9958	.9960	.9893	.9898	3.40	3.25	66.48	66.36	- 4.4	+ 4.6
CH-47B/C	Engine, T55L7C (2-000-030-22)	Ovhl	1800	258.9	348.0	.9930	.9949	.9848	.9886	90.25	67.14	76.40	74.48	-25.6	+34.4
CH-47B/C	Engine Transmission (114D6200-3/-5)	New	900	279.2	297.6	.9937	.9941	.9876	.9884	54.10	50.75	71.60	71.56	- 6.2	+ 6.6

dollar improvement (in both relative and absolute terms) is shown for the CH-47 B/C engine, T55 L7C, with over 25 percent reduction in cost from $90/FH to $67/FH. For all components examined, the average cost is reduced from $60.76 to $56.24, or 7.44%.

Both reliability and availability are improved for all components. The magnitude of improvement for an individual component is not as significant in appearance as the cost reduction, but its importance should not be overlooked. For example, the reliability for the T55 L7C engine (overhauled) increased from .9930 to .9949. These figures can be expanded by a rough rule of thumb [2/] to show, for an entire aircraft drive train, reliabilities of .9595 and .9613 respectively. Out of 1000 missions, 41 would be expected to encounter a drive train failure which could in turn result in a mission or flight abort condition. With improved diagnostic (improved technique, additional monitoring devices, etc.) this figure would be reduced to 39 failures.

The cost savings by individual component becomes quite significant when multiplied by the cumulative number of flight hours logged by the specific aircraft system. For example, the total flight hours reported on the OH-58A for Fiscal Year 75 (FY75) amounted to 315,720. Applying the respective cost savings through improved diagnostics by component and type would yield the following potential dollar savings during this period of time:

	Potential Dollar Savings
OH-58A Engine (New)	$1,853,276
OH-58A Engine (Ovhl)	2,358,428
OH-58A Main Transmission	820,872
OH-58A Tail Rotor Gearbox (New)	47,358

If it was assumed that the engine, transmission and tail rotor gearbox were all new in the OH-58A during this time period, then a maximum cumulative cost savings of $2,721,506 could be realized on the OH-58A during FY75 by implementing improved diagnostics on thése components.

[2/] Using the results of an earlier COBRO analysis of the CH-47 (TR 9-8, 16 September 1975), the R for the engine was found to be .9969, and for the entire aircraft .9633. Using this same ratio, the R for the present aircraft configuration can be estimated to be .9663 for the total aircraft.

The reader is referred to COBRO TR9-14, [1] "AMSEC User's Guide," June 1976, for a full description of the methodology used in the analysis presented in Table 13.

VALIDITY OF CURRENT DIAGNOSTIC DEVICES/TECHNIQUES/PROCEDURES

Each of the field-removal cases for each component under investigation was studied to determine the primary indication of trouble which triggered the removal, as set forth in the EIRs, and to determine the relative validity of these removals in light of the later DIR findings. From this it is possible to display the relative effectiveness of each of the diagnostic techniques for removal decisions. The results of this analysis are tabulated in Table 14 for each component. The valid removals are defined as actual component failure due to either intrinsic or extrinsic modes. The invalid removal column indicates the number of removals that showed no defect of the component upon teardown and could have remained in service. The unknown primary indicators were also included in the table to provide an overall picture of the relative effectiveness of the current diagnostic procedures/devices/techniques by component. Some of the significant findings provided in Table 14 are as follows:

- The dominant indicators for removals for all engine types are: unusual noise, chip detector, fluid leakage and Foreign Object Damage (FOD). Of these indicators,
  "Noise" was valid 86% of the time
  "Chip Detector" was valid 82% of the time
  "Fluid Leakage" was valid 100% of the time
  "FOD" was valid 85% of the time

- Engine removals generated by AOAP indicates a high credibility of this diagnostic capability with a 90% valid removal rate.

- All removals of the engines generated by visual inspection were found to be valid, indicating that the most reliable technique is the actual inspection of the component.

- Transmission data was quite limited with most removals (8) being generated by visual inspection, which was 75% valid.

- Chip detector removals for the transmissions were valid 66% of the time as compared with the 82% valid for the engines.

TABLE 14. VALIDITY OF PRIMARY INDICATORS

Primary Indication from EIR **Generating Removal**	Total DIR Removals	Disassembly Inspection Results: Valid Removal	Disassembly Inspection Results: Invalid* Removal
Model: AH-1G & UH-1H	Component: Engine, T53L13A/B		
Unusual noise	21	19	2
FOD ingested	13	11	2
Engine chip **detector**	14	10	4
Fluid leakage	10	10	-
Compressor stall	8	8	-
Visual inspection	8	8	-
RPM **warning instrument**	6	3	3
EGT **increase**	4	3	1
Vibration	3	2	1
Oil **pressure** low	3	3	-
AOAP lab **requested removal**	3	3	-
Excessive oil consumption	2	2	-
Contamination	2	2	-
Metal particles in oil filter	2	-	2
Smoke or fire	2	2	-
Engine oil temperature increased	2	-	2
Engine would not start	1	1	-
Metal on oil screen	1	-	1
Engine surging	1	1	-
Unknown	210	145	65
Total	316	233	83
Model: AH-1G & UH-1H	Component: Main Transmission		
Visual inspection	2	2	-
AOAP lab requested removal	1	1	-
Gearbox chip detector	1	-	1
Unknown	18	9	9
Total	22	12	10
Model: AH-1G	Component: 90° Gearbox		
Unknown	12	7	5
Total	12	7	5
Model: UH-1H	Component: 90° Gearbox		
AOAP lab requested removal	9	3	6
Gearbox chip detector	5	3	2
Unusual noise	2	-	2
Vibration	1	-	1
Fluid leakage	1	1	-
Unknown	54	21	33
Total	72	28	44
Model: OH-58A	Component: Engine, T63A700		
Noise	16	14	2
Engine chip detector	8	7	1
Fluid leakage	7	7	-
AOAP lab requested removal	4	3	1
Hot start	3	2	1
Smoke or fire	3	3	-
Oil temperature increased	3	2	1
Engine would not start	2	-	2
Visual inspection	2	2	-
EGT increased	2	1	1
Vibration	2	-	2
Oil pressure low	2	1	1
Excessive oil consumption	2	2	-
Engine oil by-pass light on	2	2	-
RPM warning instrument	2	2	-
RPM warning light	1	-	1
RPM warning, audio	1	1	-
Rotor tachometer high	1	1	-
Engine oil pressure high	1	1	-
Unusual altitude	1	1	-
FOD ingested	1	1	-
Master warning light	1	1	-
Unknown	175	138	37
Total	242	192	50

*/Invalid Removal indicates that no defects were found upon teardown for failure or non-failure modes, and that the component could have remained in service.

TABLE 14. Continued

Primary Indication from EIR Generating Removal	Total DIR Removals	Disassembly Inspection Results: Valid Removal	Invalid Removal
Model: OH-58A — Component: Main Transmission			
Visual inspection	5	3	2
Unusual noise	2	1	1
Transmission chip detector	1	1	-
Unknown	13	4	9
Total	21	9	12
Model: OH-58A — Component: Tail Rotor Gearbox			
Visual inspection	2	2	-
AOAP lab requested removal	2	2	-
Chips on mag plug-inspection	1	1	-
Gearbox chip detector	2	-	-
Unknown	3	4	-
Total	9	9	0
Model: CH-47B/C — Component: Engine, T55L11A			
Unusual noise	3	1	2
Vibration	2	2	-
Visual inspection	2	2	-
Unknown	15	13	2
Total	22	18	4
Model: CH-47B/C — Component: Engine, T55L7C			
Engine chip detector	5	5	-
AOAP lab requested removal	3	3	-
Unusual noise	2	2	-
Engine surging	2	2	-
EGT increase	1	1	-
Unknown	24	21	3
Total	36	33	3
Model: CH-47B/C — Component: Engine Transmission			
Transmission chip detector	1	1	-
Unknown	7	5	2
Total	8	6	2
Model: CH-47B/C — Component: Forward Transmission			
Visual inspection	1	1	-
Unknown	7	6	1
Total	8	7	1
Model: CH-47B/C — Component: Aft Transmission			
Unusual noise	1	1	-
Unknown	8	7	1
Total	9	8	1

Note: Data for the UH-1H and AH-1G 42° Gearbox was not applicable in this analysis.

- The removals generated by AOAP against the gearboxes indicate a low diagnostic capability for these components with only 45% effectively valid.

- Removals generated by the chip detector in the gearboxes also indicated a low capability with only 50% valid as compared to 66% for the transmissions and 82% for the engines.

RELATION OF PRIMARY FAULT INDICATORS TO DEGREE OF DAMAGE

It becomes significantly important to link the current diagnostic indication to the resulting degree of damage or loss of mission effectiveness resulting from that indication. Table 15 presents the percentage of the Primary Fault Indicators by component that generated the degree of damage in terms of mishap classifications. Significant findings in this table include:

- Unusual noise was the leading diagnostic indicator for engine mishaps resulting in an average of 36% of the primary indications that led to a damaging effect upon the aircraft.

- Engine chip detectors were responsible for an average of 17% of the initial indications leading to a precautionary landing, while comparatively, transmission chip detectors were responsible for 52% and gearbox chip detectors 63%.

VALIDITY OF REMOVAL AUTHORIZATIONS

Table 16 provides a display of the number of removals that were made, for different components, by virtue of different types of authorization; for each of these groups of removals, the table indicates the number and percentage of those which were valid.

For example, for the OH-58A engine, a total of 242 removals were made. Of these, 76 were authorized by EIR and were 73.7% valid; 36 were authorized by TSARCOM directive and were 100% valid; 46 were authorized by USAAAVS and were 84.8% valid; and 84 were authorized by AOAP and were 71.4% valid.

Out of 798 removals included in Table 16, 72.3% were valid. Those authorized by TSARCOM directive and by EIR proved to have the highest average validity, 74.7% and 74%, respectively. The removals authorized by AOAP showed the lowest validity at 65.7%

TABLE 15. PRIMARY FAULT INDICATORS BY MISHAP CLASS

Mishap Class	First Indications	Percent	Mishap Class	First Indications	Percent
AH-1G & UH-1H Engine, T53L13A/B					
Total Loss	RPM warn. instr.	31.25	Precautionary landing (cont)	RPM warn. lt.	1.7
	Faulty operation	18.75		Fuel	1.1
	Unusual noise	18.75		Fluid leakage	1.1
	Unusual attitude	6.25		RPM warn. audio	.8
	Vibration	6.25		Smoke or fire	.8
	Undetermined	6.25		XMSN chip det.	.8
	Other personnel	6.25	AH-1G & UH-1H Main Transmissions		
Major substantial damage	Unusual noise	47.0	Precautionary landing	Mstr. warn. lt.	66.0
	Mstr. warn. lt	23.5		Odor	33.0
	Vibration	11.8	AH-1G & UH-1H 90° Gearbox		
	Faulty operation	11.8	Major substantial damage	Gearbox chip det.	50.0
	Annunciator panel	5.9		Vibration	50.0
Minor	Faulty operation	100.0	Incident	Faulty operation	100.0
Incident	Unusual noise	50.0	Precautionary landing	Gearbox chip det.	59.5
	RPM warn. instr.	10.0		Mstr. warn. lt.	29.7
	Mstr. warn. lt.	10.0		Unusual attitude	2.7
	RPM warn. lt.	10.0		Unusual noise	2.7
	Faulty operation	10.0		Fluid leakage	2.7
	Annunciator panel	10.0		Annunciator panel	2.7
Forced landing	Unusual noise	31.8	OH-58A, Engine		
	RPM warn. instr.	22.3	Total loss	Unusual noise	50.0
	Faulty operation	12.8		Faulty operation	25.0
	Vibration	10.6		Annunciator pnl.	25.0
	Unusual attitude	6.4	Major substantial damage	Unusual noise	40.0
	Mstr. warn. lt.	6.4		RPM warn. instr.	30.0
	RPM warn. lt.	5.3		Faulty oper.	20.0
	Other	1.1		Mstr. warn. lt.	10.0
	Smoke or fire	1.1	Incident	Unusual noise	25.0
	Annunciator panel	1.1		Faulty oper.	12.5
	Voice warning	1.1		Eng. chip det.	12.5
Precautionary landing	Mstr. warn. lt.	19.9		RPM warn. lt.	12.5
	Unusual noise	19.4		Vibration	12.5
	Faulty operation	13.9		RPM warn. instr.	12.5
	Eng. chip det.	11.9		Unusual attitude	12.5
	RPM warn. instr.	10.0			
	Oil	5.3			
	Annunciator panel	5.0			
	Odor	3.6			
	Unusual attitude	2.5			
	Vibration	2.2			

TABLE 15 (Cont)

Mishap Class	First Indications	Percent
OH-58A, Engine (Cont)		
Forced landing	Unusual noise	25.7
	RPM warn. inst.	22.9
	Faulty operation	10.4
	Mstr. warn. lt.	9.4
	Unusual attitude	7.3
	Vibration	5.2
	RPM warn. audio	4.2
	Eng. chip det.	4.2
	RPM warn. lt.	4.2
	Annunciator panel	2.1
	Fluid leakage	1.1
	Odor	1.1
	Oil	1.1
	Smoke or fire	1.1
Precautionary landing	RPM warn. instr.	20.3
	Eng. chip det.	18.1
	Faulty operation	15.9
	Mstr. warn. lt.	15.2
	Unusual noise	8.0
	Annunciator panel	8.0
	Fluid leakage	3.6
	Vibration	2.9
	Smoke or fire	2.2
	Unusual attitude	2.2
	Oil	2.2
	Fuel	.7
	RPM warn. lt.	.7
OH-58A Main Transmission		
Precautionary landing	XMSN chip det.	58.8
	Mstr. warn. lt.	29.4
	Annunciator panel	5.9
	Faulty operation	5.9
OH-58A T/R Gearbox		
Precautionary landing	Gearbox chip det.	66.7
	Mstr. warn. lt.	33.3

Mishap Class	First Indications	Percent
CH-47B/C Aft, Fwd & Eng. XMSN's		
Forced landing	Unusual noise	100.0
Precautionary landing	XMSN chip det.	46.1
	Mstr. warn. lt.	38.5
	Unusual noise	7.7
	Vibration	7.7
CH-47B/C Engines, T55L7C & T44L11A		
Precautionary landing	Eng. chip det.	21.6
	RPM warn. instr.	21.6
	Unusual noise	18.9
	Faulty operation	16.3
	Mstr. warn. lt.	13.5
	Fluid leakage	5.4
	Vibration	2.7

TABLE 16. SUMMARY OF THE NUMBER OF DISASSEMBLY INSPECTION REPORTS REVIEWED BY AUTHORIZATION TYPE AND PERCENT OF VALID REMOVALS
Period Covered: Jan. 1972-Oct. 1977

A/C Model	Nomenclature	Part Number(s)	EIR # of DIRs	EIR % Valid	TSARCOM Directives # of DIRs	TSARCOM Directives % Valid	USAAAVS # of DIRs	USAAAVS % Valid	AOAP # of DIRs	AOAP % Valid	Total for All Types # of DIRs	Total for All Types % Valid
OH-58A	Engine, T63A700	6874201	76	73.7	36	100.0	46	84.8	84	71.4	242	78.9
OH-58A	Main XMSN	206-040-003-5	3	66.6	11	27.3	2	100.0	5	40.0	21	42.9
OH-58A	Tail Rotor Gearbox	206-040-400-7/-9	1	100.0	1	100.0	2	100.0	5	100.0	9	100.0
AH-1G	90° Gearbox	209-040-400-11	1	100.0	0	---	7	57.1	4	50.0	12	58.3
AH-1G	Engine, T53L13A/B	1-000-060-08/-10	11	90.9	4	50.0	24	70.8	17	70.6	56	75.0
AH-1G & UH-1H	Main XMSN	204-040-016-1/ -3/-5	5	40.0	0	---	6	83.3	11	45.5	22	54.5
UH-1H	Engine, T53L13A/B	1-000-060-08/-10	97	77.3	13	69.2	77	74.0	73	67.1	260	73.1
UH-1H	90° Gearbox	204-040-012-13	8	50.0	4	0.0	15	33.3	45	42.2	72	38.9
CH-47B/C	Engine, T55L7C	2-000-030-22	8	100.0	2	100.0	9	100.0	17	82.4	36	91.7
CH-47B/C	Fwd. XMSN	114D1200-3/-5/ -6/-7 114D1001-27	3	100.0	2	50.0	1	50.0	2	100.0	8	87.5
CH-47B/C	Aft XMSN	114D2200-7/-8/-9 114D2200-5/-8	1	50.0	1	---	4	100.0	3	100.0	9	88.9
CH-47B/C	Engine XMSN	114D6001-19/-20 114D6200-2/-3	0	---	3	66.7	4	75.0	1	100.0	8	75.0
CH-47C	Engine, T55L11A	2-001-020-05	8	62.5	3	100.0	5	100.0	6	83.3	22	81.8
UH-1H & AH-1G	42° Gearbox	204-040-003-3	1	0.0	3	100.0	10	90.0	7	71.4	21	81.0
Total			223	74.0	83	74.7	212	68.4	280	65.7	798	72.3

For all reasons for removals, it becomes significant to note the following percentages of valid removals for the generic components:

Engines	-	77% Valid
Transmissions	-	62% Valid
Gearboxes	-	54% Valid

These percentages tend to support existing views on the current diagnostic capabilities of these generic components. Although engines possess a relatively higher removal validity percent than transmissions and gearboxes, a determination of the minimum acceptable level of diagnostic capability within the constraints of mission effectiveness, safety and cost may indicate that even this relatively high figure is too low.

RECOMMENDATIONS

On the basis of this study, the following recommendations are offered:

Expanded Effort to Optimize Dollar Savings through Preclusion of Premature False Removals by Improving Diagnostic Effectiveness

The objective of this analysis was to determine the effectiveness of the current diagnostic procedures, techniques and devices of the components under study. The results provide a very significant basis for continual investigation of the present removal criteria at the unit maintenance level correlated with the depot feedback of valid versus invalid removal.

The data reviewed under this analysis indicates that a very large number of aircraft major items are in the depot overhaul facilities for reasons other than meeting TBO. For instance, of the total UH-1H, prior overhauled T53L13A/B engines that were sent to depot overhaul for the period 1 Jan 1964 through 1 July 1976, 67% were premature removals. Based upon the sample DIRs for the same component, it was determined that 73% of the removals were actually valid. If one could assume that the DIR sample is representative of all premature removals for the T53 engine, then an estimate of 27% of the engines would have shown no defects and could have remained in service. The cost savings as provided through the AMSEC results are approximately $5.00 per operating hour. Multiplying this figure by the estimated 500,000 flight hours being logged per year on the UH-1H would yield a cost savings of $2,500,000 per year generated by invalid engine removals. Applying this same philosophy across the board for all major items on all Army aircraft systems would introduce phenomenal savings to the Army. Therefore it is strongly recommended that the Army institute a program to complete the feedback loop from the depot overhaul facilities so that the relationship of unit removal criteria versus the valid-invalid removal result can be determined by component for the major Army aircraft systems. These results would then provide the basis for focussing upon the most sensitive diagnostic discipline, whether it be improved devices or additional techniques and procedures in the maintenance concept. These findings in turn would be used to optimize the dollar savings while improving mission reliability and availability with minimal initial research and development expenses to the Army.

Extension to Cover Field Diagnostic Errors of Omission

The analysis described in this report is based on a comparison of equipment condition as it is diagnosed in the field and as

it is diagnosed under engineering teardown and inspection. However, the only components which are subjected to the latter examination are those which were removed due to some indication of malfunction as determined by the unit level maintenance. Those components which, in the opinion of aviation unit maintenance should not be removed are not subjected to the DIR procedures, so that errors of omission by aviation unit maintenance are not caught. It is suggested that a plan be designed to draw, from those field components which are not thought to require replacement, a sample of components which would be forwarded to depot for analysis. For those components which, in the opinion of engineers, should have been removed from service earlier, an algorithm can be developed analagous to that described in the preceding section to determine when they should have been removed if AVUM had 100% effective diagnostic capability.

APPENDIX A
REMOVAL CODES

TABLE A-1. MAJOR COMPONENT REMOVAL CATEGORIES

01	QUALITY CONTROL Defective Material
02	OBSERVATION Broken or malfunctioning
03	MEASUREMENT Out-of-tolerance
04	DIAGNOSTICS, INSTRUMENTS Status tests, measures
05	SEALS, LEAKS Excessive leaking
06	FAILURE Physical break, rupture, seizure
07	MAINTENANCE Erroneous actions
08	ENVIRONMENT Foreign object contamination
09	CRASH, BATTLE ACCIDENT Physical damage during encounter
10	OPERATIONS Overstress
11	OTHER Not covered by above
12	MAINTENANCE Scheduled actions
13	SUPPLY/CONVENIENCE Administrative, erroneous actions

TABLE A-2. CLASSIFICATION OF REPORTED REMOVAL CODES BY CATEGORY

Field Removal Code	Removal Category
002-Air leak	5
003-Open filament tube cir.	2
004-Low GM or emission	3
007-Arcing, arced	2
008-Noisy	2
009-Microphonic	3
013-Loose base	2
018-Tested OK; did not work	2
020-Worn excessively	3
021-Overloaded	10
023-Blown	6
024-Calibration incorrect	3
025-Capacitance incorrect	3
027-Collapsed	2
028-Conductance incorrect	3
029-Current incorrect	3
030-Damaged	2
031-Alignment improper	3
032-Defective	6
037-Fluctuates, unstable	4
040-Mechanical binding	2
050-Blistered	2
060-Brittle	2
061-Fused	2
064-Incorrect modulation	4
066-Human error	13
068-Inoperative	4
069-Flameout	4
070-Broken	6
072-Insufficient heat dissipation	2
077-Insufficient protection from moisture	2
080-Burned out	2
086-Improper handling	7
088-Incorrect gain	3
090-Brushes, improper tension	3
092-Mismatched	13
093-Missing part	7
095-Improper lubrication	7
099-Other (explain)	13
101-Armature dirty	2
105-Loose, bolts, nuts, screws	7
106-Missing bolts, nuts, screws	7
108-Broken or missing safety wire or key	7
109-Buckled	2
111-Burst	6
112-Carboned	6
113-Clutch slips	6
116-Cut	2
117-Deteriorated	2
119-Disintegrated	2
120-Chafed	2
123-Brinelled	2
127-Adjustment improper	3
130-Change of value	4
131-Marginal part replaced	13
135-Binding	2
137-Engine removed, overhaul scheduled	12
138-Engine removed, engine modification	13
139-Engine removed, ACFT modification	13
142-Engine removed, excessive maint.	13
147-Missile engine, stricken	2
148-Eroded	8
150-Chattering	2
154-Overstressed	10
160-Contact/connection defective	2
165-Timing incorrect	6
167-Torque incorrect	7
169-Incorrect voltage	4
170-Corroded	2
171-Burred	2
177-Fuel flow incorrect	3
178-Fuel flow low	4
179-Fuel pressure erratic	4
180-Clogged	8
181-Low compression	2
185-Contaminated with metal	6

TABLE A-2 (Con't)

Field Removal Code	Removal Category	Field Removal Code	Removal Category
190-Cracked	2	304-Foreign object damage, origin unknown	8
192-Defective material	1	306-Contamination	4
193-Deposits	2	307-Oil leak	5
196-Shorted	2	308-Oil contamination	4
200-Dented	2	310-Handling improper	7
203-Fitting leak	5	311-Hard landing	9
205-Explosion, engine	2	314-Slow acceleration	4
210-Detent action poor	2	315-RPM fluctuation	4
212-Fluted	4	317-Hot start	10
214-Fails diagnostic	4	318-Slow de-acceleration	4
217-Hen-tracked	2	320-High voltage breakdown	2
221-Collision	10	330-Excessive hum	2
223-Deformed	2	334-Temperature incorrect	4
225-Manufacturer defect	1	335-Improper loading	7
230-Dirty	7	336-Improper operation	10
231-Elongated	3	337-Improperly serviced	7
232-End play excessive	3	338-Malfunctioning	2
233-Erratic	2	340-Installed improperly	7
235-Dry	2	341-Temperature indication faulty	4
236-Hydro lock	6	343-ACFT temperature indication error	4
237-Improper assembly mfg	7	346-Misaligned	7
239-Improper fit	2	347-Mishandled	7
240-Flaking	2	349-Low frequency vibration	2
242-Failed to operate	2	350-Insulation breakdown	2
247-Improperly machined	1	351-High frequency vibration	2
250-Frayed	2	352-Engine vibration	2
251-Low lube pressure	4	355-High engine power	4
252-Lubrication omitted	7	356-Low engine power	4
255-No output	4	357-Erratic engine power	4
259-Oversize	1	360-Intermittent operation	6
260-Friction excessive	2	366-Removed unnecessarily	7
263-Poor bonding	1	370-Jammed	6
266-Poor welding	1	371-Cocked	2
271-Sprung	2	372-Metal on magnetic plug	4
273-Sticks	6	373-Stripped threads	7
275-Undersize	1	374-Internal failure	6
277-Fuel nozzle coking	2	376-Magnetic indication	4
281-High reading	4	380-Scheduled maintenance	12
282-Low reading	4	381-Leaking	5
283-Leaks oil	5	382-Liquid lock	6
284-Leaks fuel	5	383-Lock on malfunction	2
290-Grooved	2	385-Loose or missing rivets	2
297-Fuel schedule shift	2	386-Lost in flight	7
300-Grounded	2		
301-Foreign object damage	8		
302-Foreign object damage, origin engine	8		

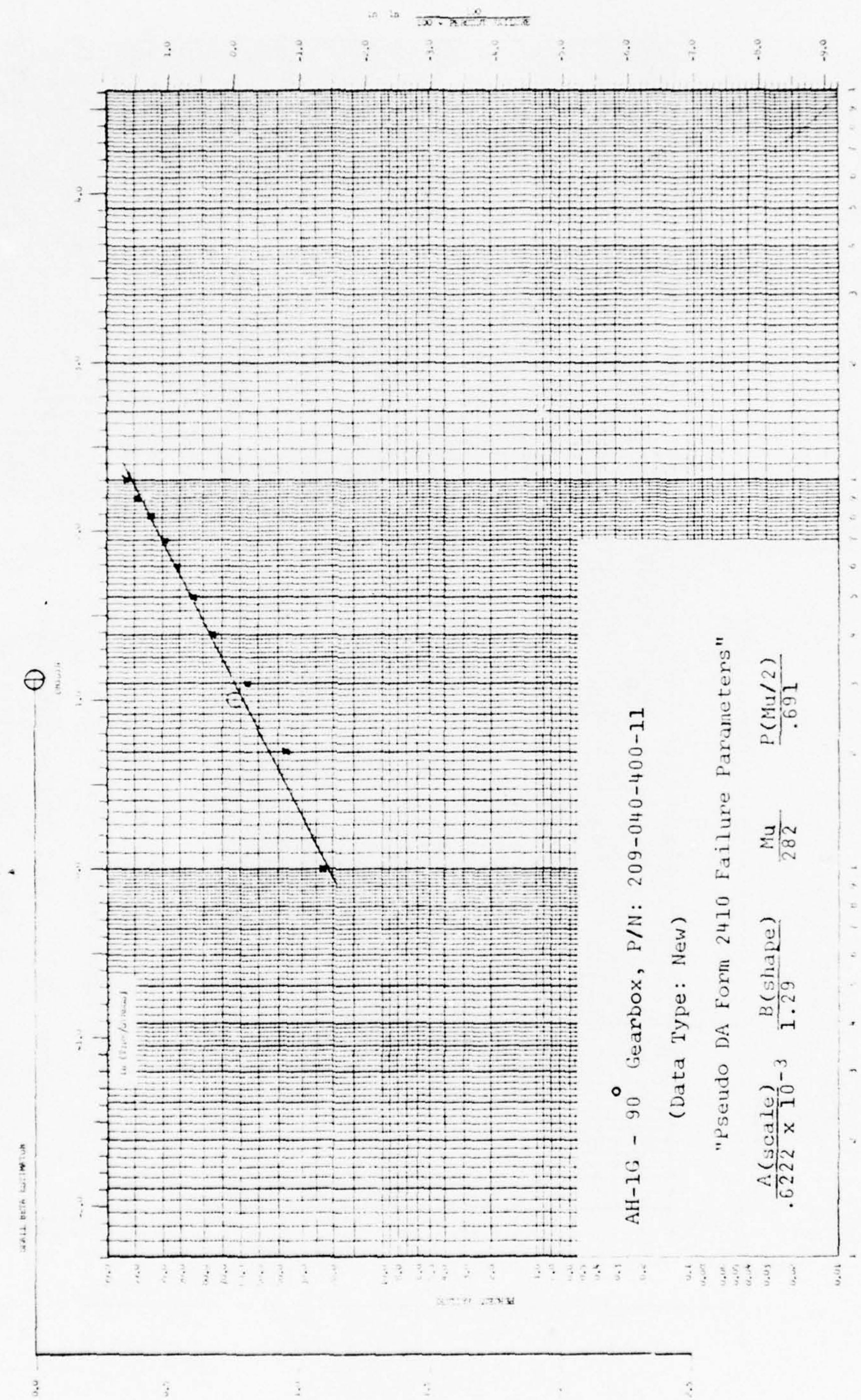
TABLE A-2 (Con't)

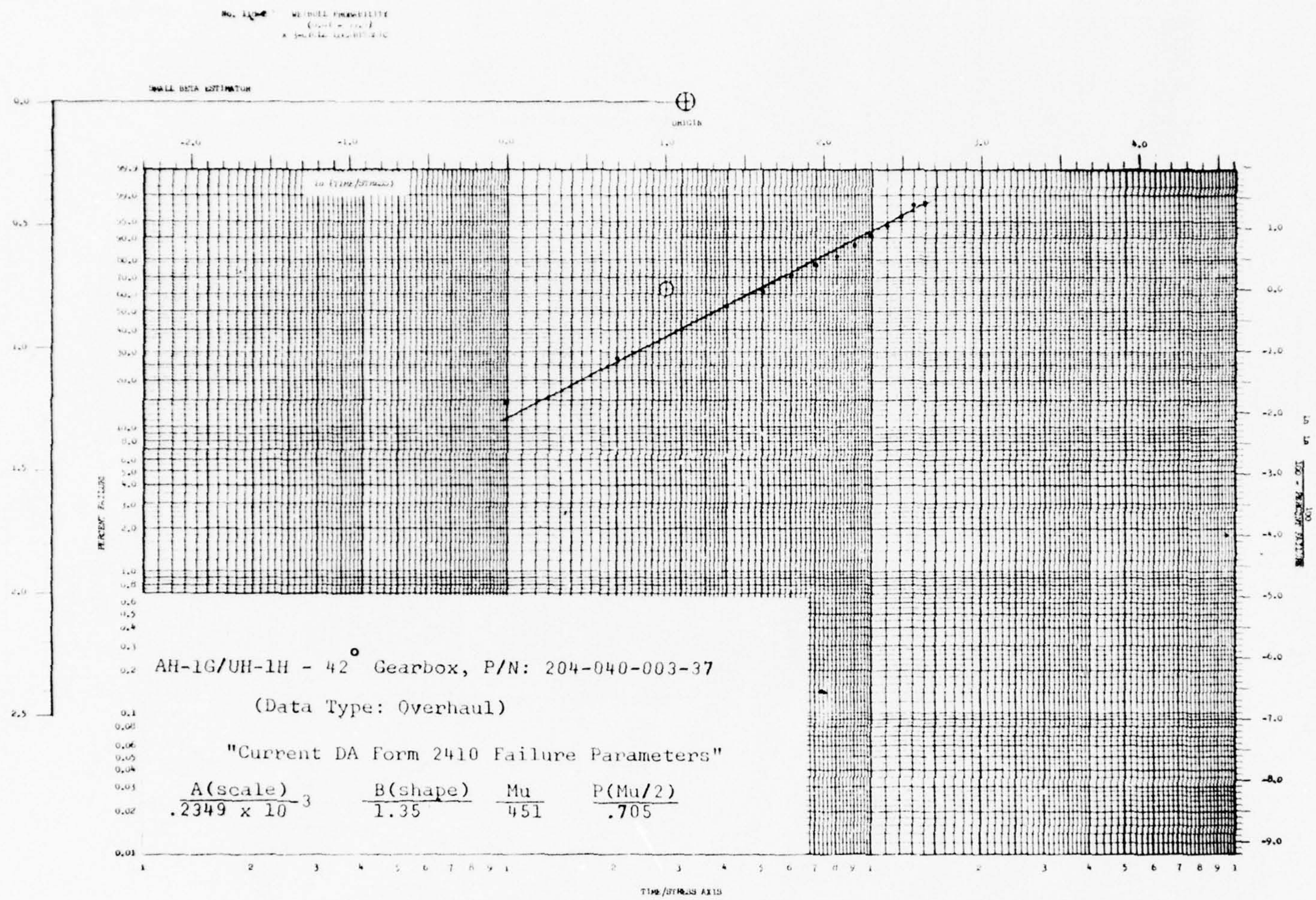
Field Removal Code	Removal Category	Field Removal Code	Removal Category
387-Low performance	4	568-Resistance low	3
394-Stuck indicator needle missile gauge	4	570-Rusty	2
396-Oil breathing excessive	5	571-RPM too high	4
397-Oil consumption low	5	572-RPM too low	4
398-Oil consumption excessive	5	574-Rubbing	2
399-Oil consumption high	5	576-Ruptured	6
405-Oil pressure erratic	4	581-Seal broken	5
407-Oil scavenging erratic	4	582-Seal leaking	5
408-Oil temperature low	4	583-Scope presentation, incorrect/faulty	4
409-Oil temperature high	4	584-Shattered	2
410-Lack of lubrication	5	585-Sheared	6
416-Out of round	3	603-Oil in induction system	2
420-Moisture saturation	8	607-Distortion	2
425-Nicked	2	622-Wet	2
430-Oil saturation	5	623-Insertion loss	2
437-Operating error	10	625-Improper time	3
438-Poor workmanship	7	635-Improper circular length	3
446-No defective part-removed in troubleshooting	13	637-Improper thickness	3
		640-Slippage	3
		645-Spurious	13
450-Open	2	650-Sticky	6
457-Oscillating	2	652-Improper weight	1
461-Output too high	4	654-Improper viscosity	3
462-Output too low	4	658-Out of flat	2
463-Output none	4	659-Improper hardness	1
464-Overspeed	10	660-Stripped	2
466-Rolled over	9	661-Temperature too high	4
472-Fuze blown	2	662-Temperature too low	4
473-Seal blown	5	666-Twisted	2
480-Overheated	3	670-Unbalanced	3
492-Scuffed	2	680-Unstable	2
497-Design deficiency	1	682-Out of position	2
481-Overheats	3	684-Improper datum	3
500-Overlubricated	7	686-Improper tracking	3
503-Sudden stop	9	687-Improper rate dependency	3
509-Spalled	6		
513-Stalls-compressor	4	688-Improper NG response	3
519-Surged	4	690-Vibration excessive	2
520-Pitted	2	693-Audio faulty	4
523-Pressure too high	4	701-Warped	2
524-Pressure too low	4	703-Improper amplitude	3
525-Pressure-none	4	704-Improper attenuation	3
537-Low power or thrust	4	705-Beyond specified problems	3
540-Punctured	8		
547-Turned	6	706-Shifted	6
551-High time	12	709-Scrapped or salvaged	13
561-Unable to adjust limits	3	710-Bearing failure	6
567-Resistance high	3	712-Crash damage	9

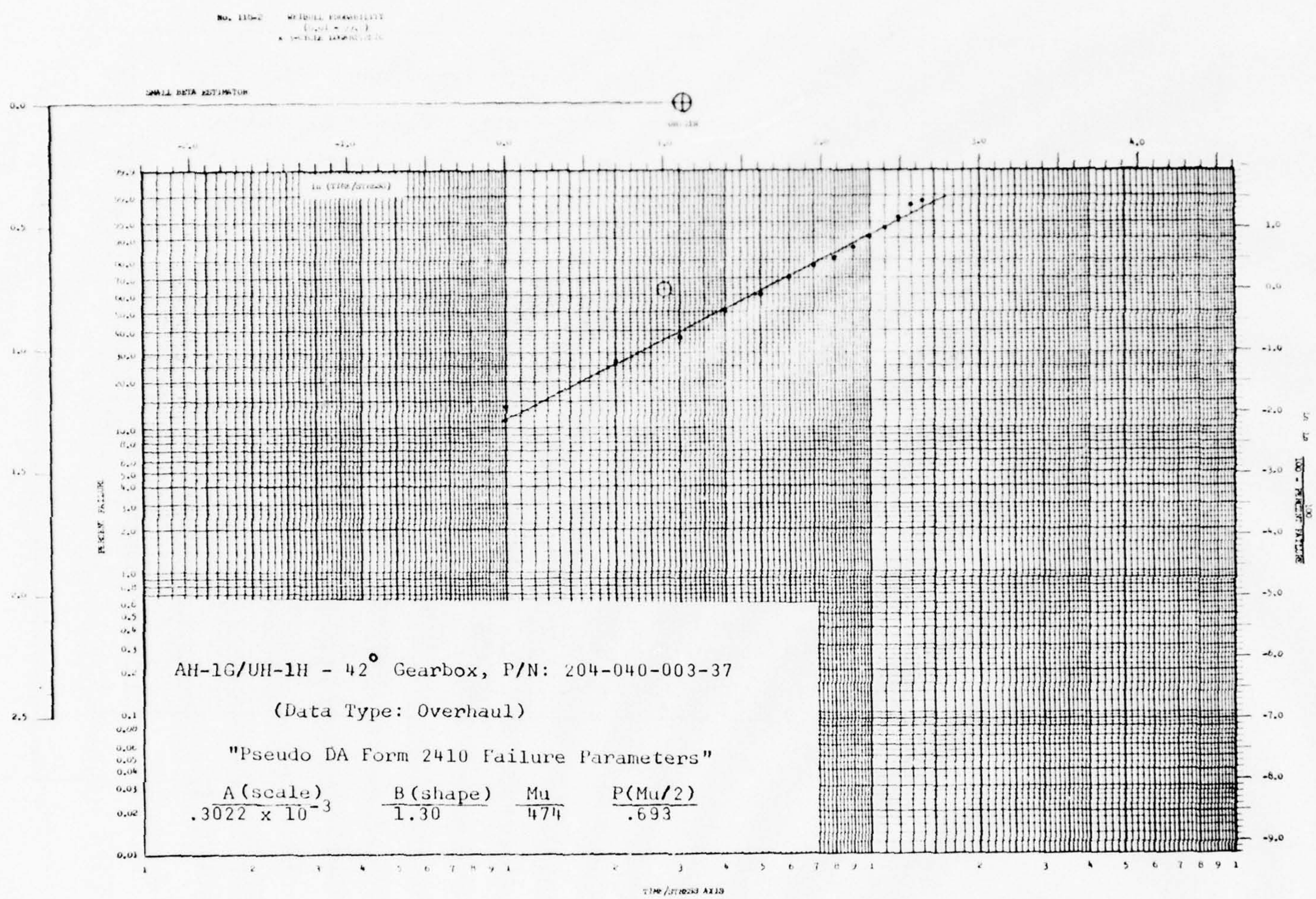
TABLE A-2 (Con't)

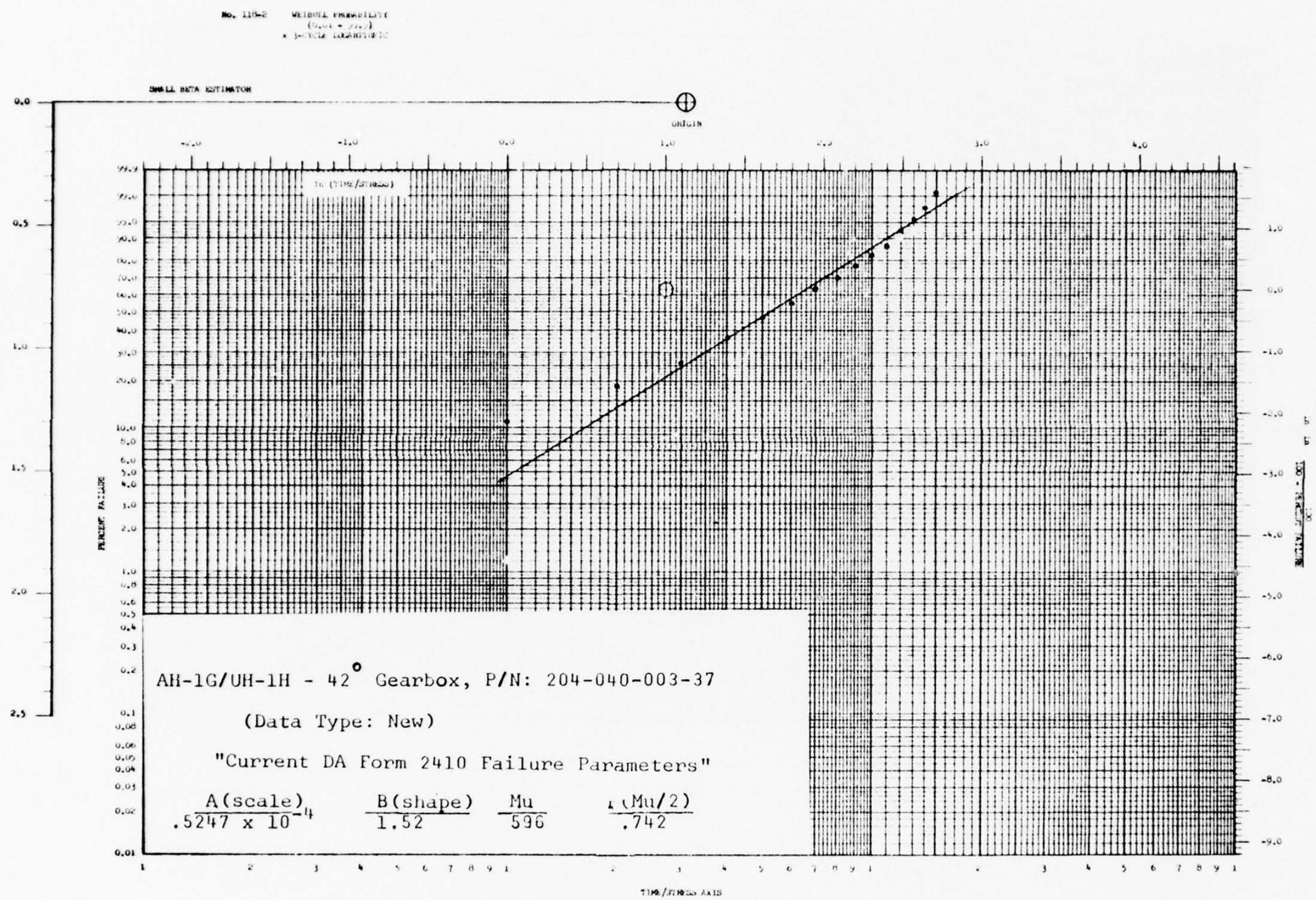
Field Removal Code	Removal Category
713-Battled damage	9
714-Cannibalization	13
715-Failure caused by other component failure	6
716-Excessive current	9
720-Brush failure/worn excessively	3
730-Loose	2
748-Frequency erratic or incorrect	4
750-Missing	7
766-Out of specification, explain	3
780-Bent	2
790-Out of adjustment	3
795-Galled	6
797-No defect-MWO previously complied with	13
798-No defect-MWO not applicable	13
799-No defect	13
800-No defect-component removed/reinstalled to facillitate other maintenance	13
801-No defect-MWO compliance	13
802-No defect-partial MWO compliance	13
803-No defect-removed for time change	12
804-No defect-removed for scheduled maintenance	12
816-Total impedance, high	3
838-B plus incorrect	3
840-Seized	6
841-Abraded	2
846-Delaminated	1
853-Fatigue cracks	6
855-Heat damage	9
859-Metal fatigue	6
865-Protective coating failure	6
869-Salt water damage	8
870-Sand damage	8
874-Sunlight damage	8
878-Weather damage	8
879-Wind damage	8
900-Burned	9
901-Intermittent	2
902-Fin, deflection, none	3
910-Chipped	2
915-Dirty-foreign matter	8
920-Not determined-explain symptoms	6
926-Out of tolerance plus	7
927-Pinched	2
935-Scored	2
945-Structural failure	6
947-Torn	2
950-Wrong part	13
960-Broken envelope	2
962-Low power (electronic)	4
964-Poor spectrum	2
976-Pitch lock engaging RPM erratic	2
977-Pressure erratic	4
978-Voltage erratic	4
979-Maintenance error	7
980-Excessive jitter	2
981-Work unauthorized	13
982-Disassembled prior to receipt	13

APPENDIX B
WEIBULL PLOTS

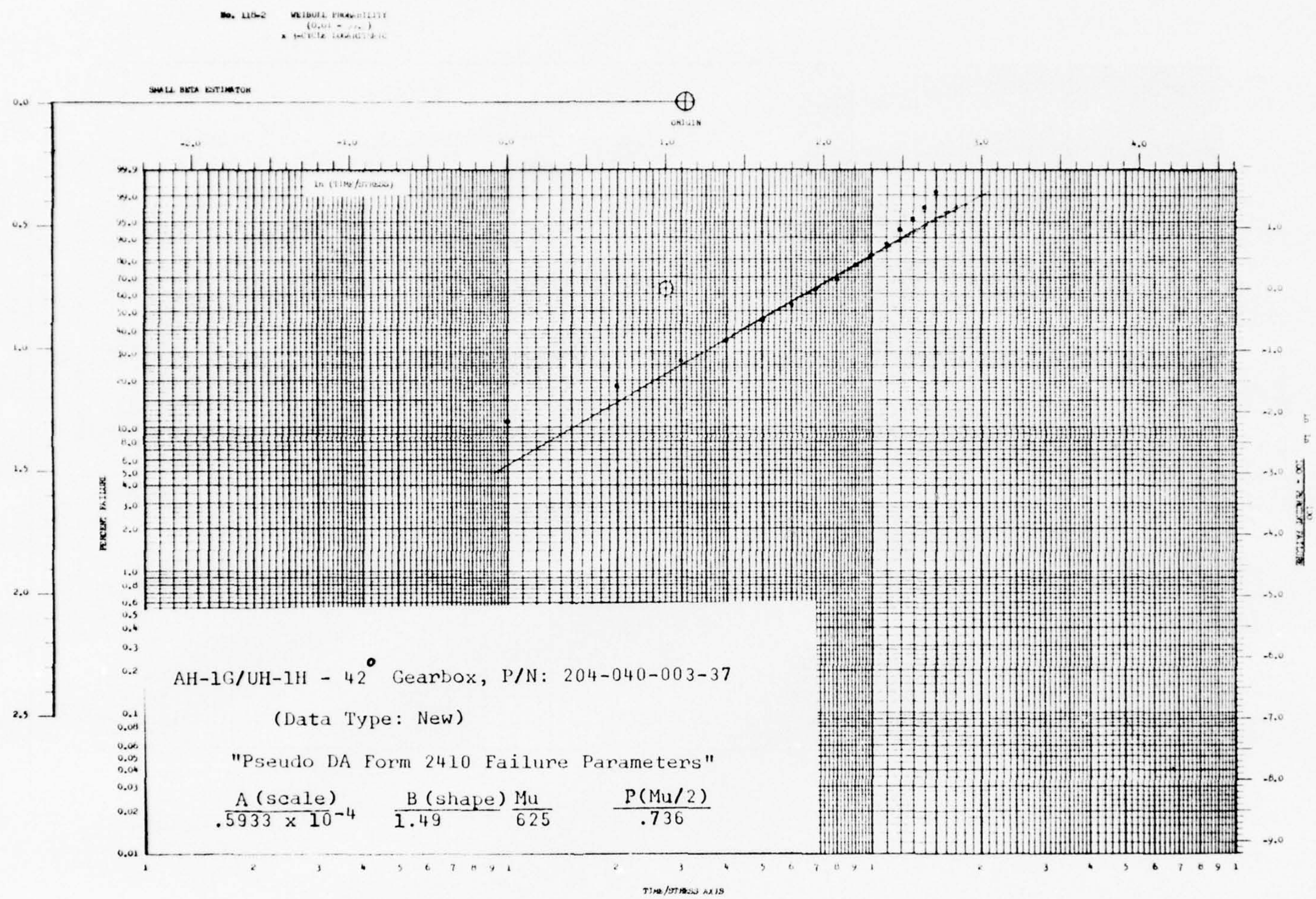


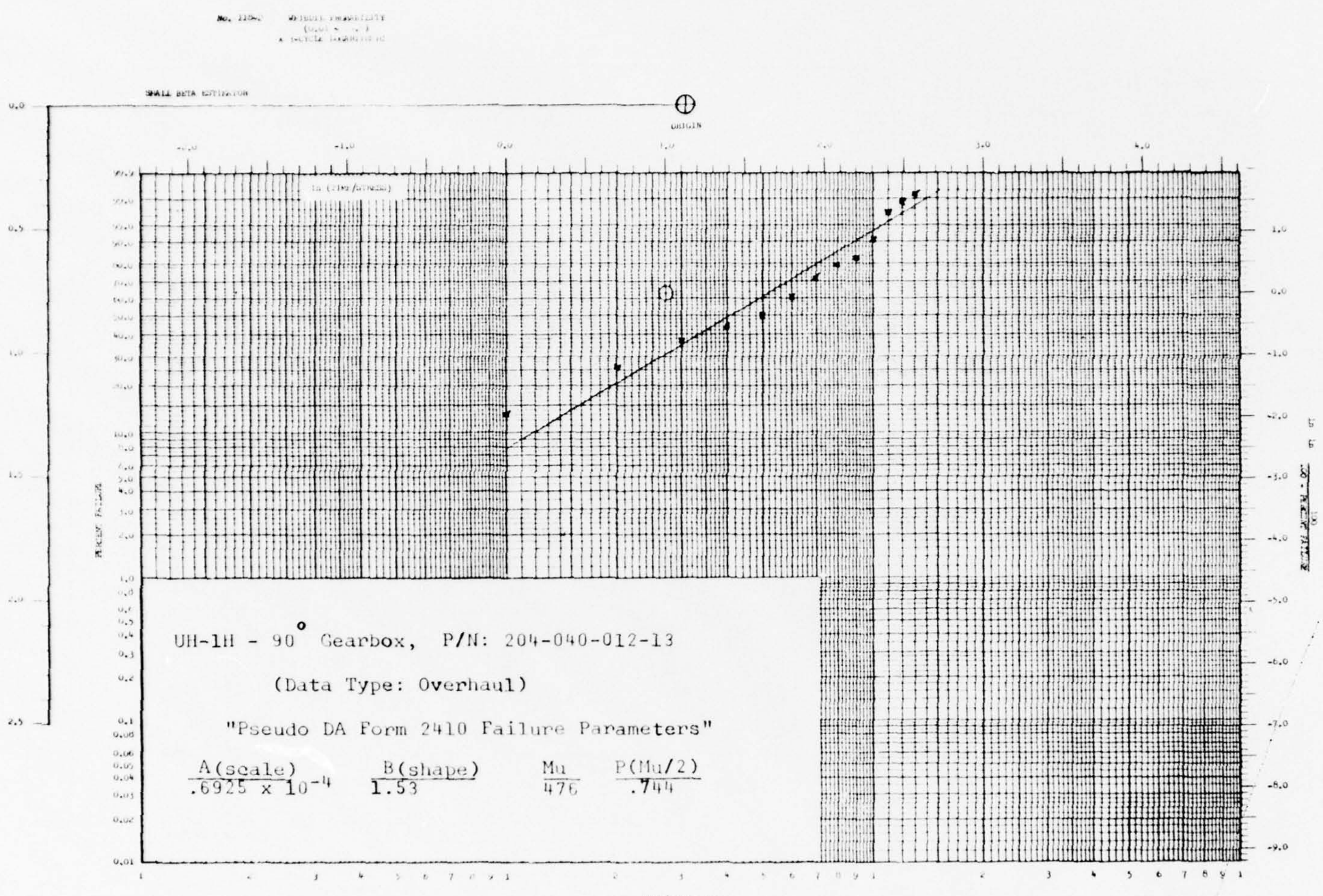

SMALL BETA ESTIMATOR
ORIGIN
TIME/STRESS AXIS
PERCENT FAILURE
AH-1G/UH-1H - 42° Gearbox, P/N: 204-040-003-37
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A(scale) .2349 x 10^-3
B(shape) 1.35
Mu 451
P(Mu/2) .705

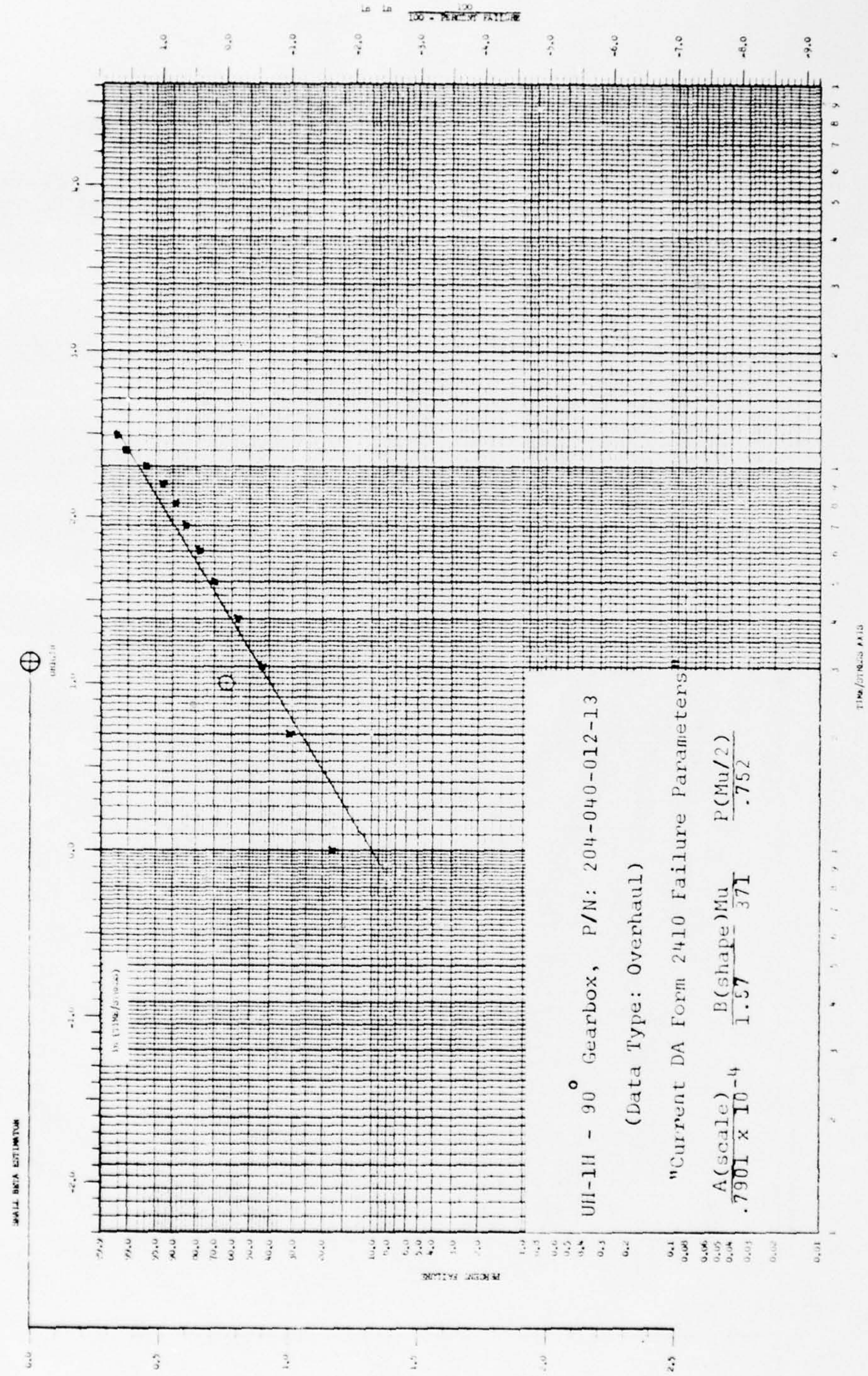

SMALL BETA ESTIMATOR
PERCENT FAILURE
TIME/STRESS AXIS
AH-1G/UH-1H - 42° Gearbox, P/N: 204-040-003-37
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A (scale) .3022 x 10-3
B (shape) 1.30
Mu 474
P(Mu/2) .693

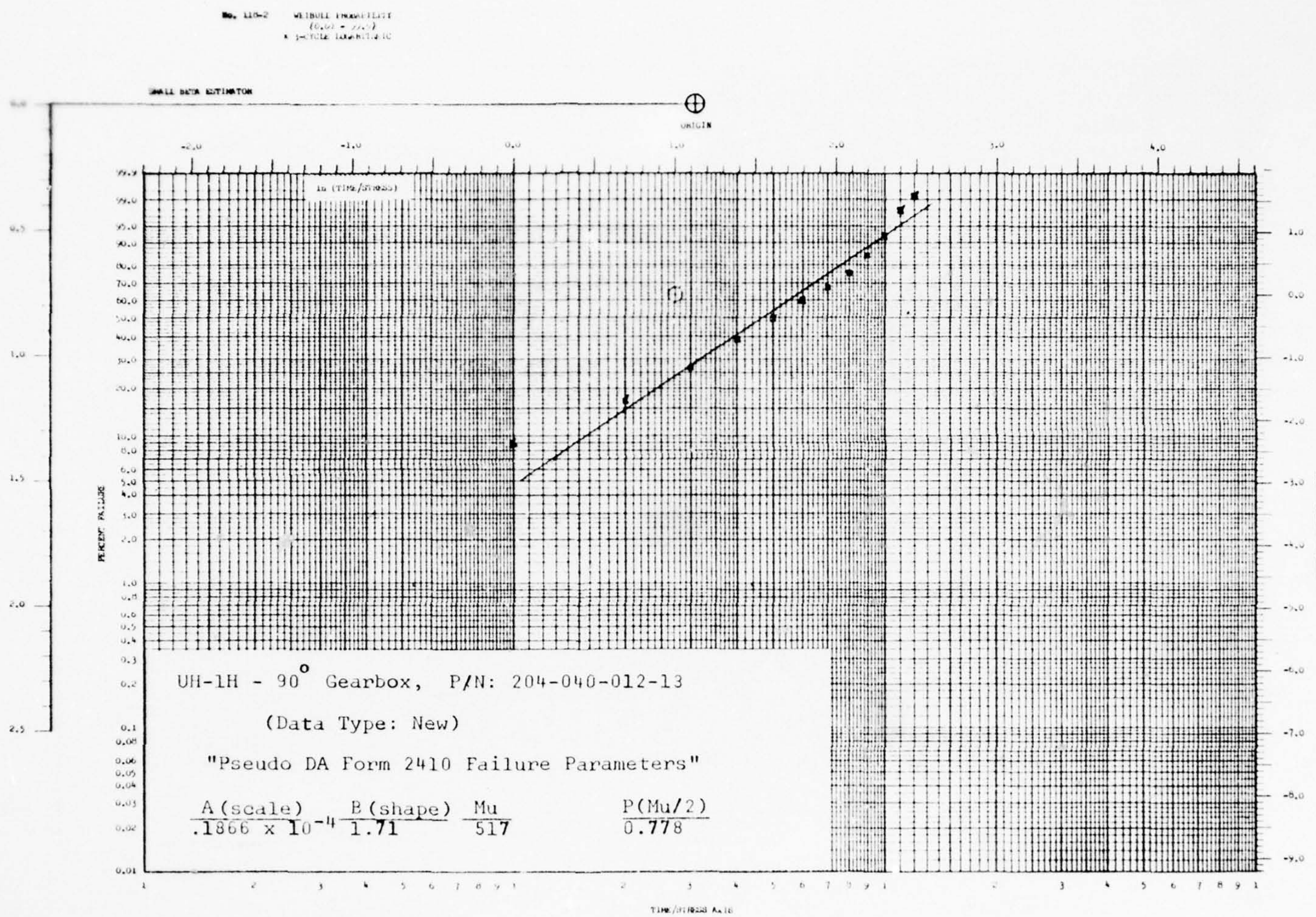


No. 118-2 WEIBULL PROBABILITY
SMALL BETA ESTIMATOR
ORIGIN
ln (TIME/STRESS)
PERCENT FAILURE
TIME/STRESS AXIS
AH-1G/UH-1H - 42° Gearbox, P/N: 204-040-003-37
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A(scale) .5247 x 10-4
B(shape) 1.52
Mu 596
Γ(Mu/2) .742

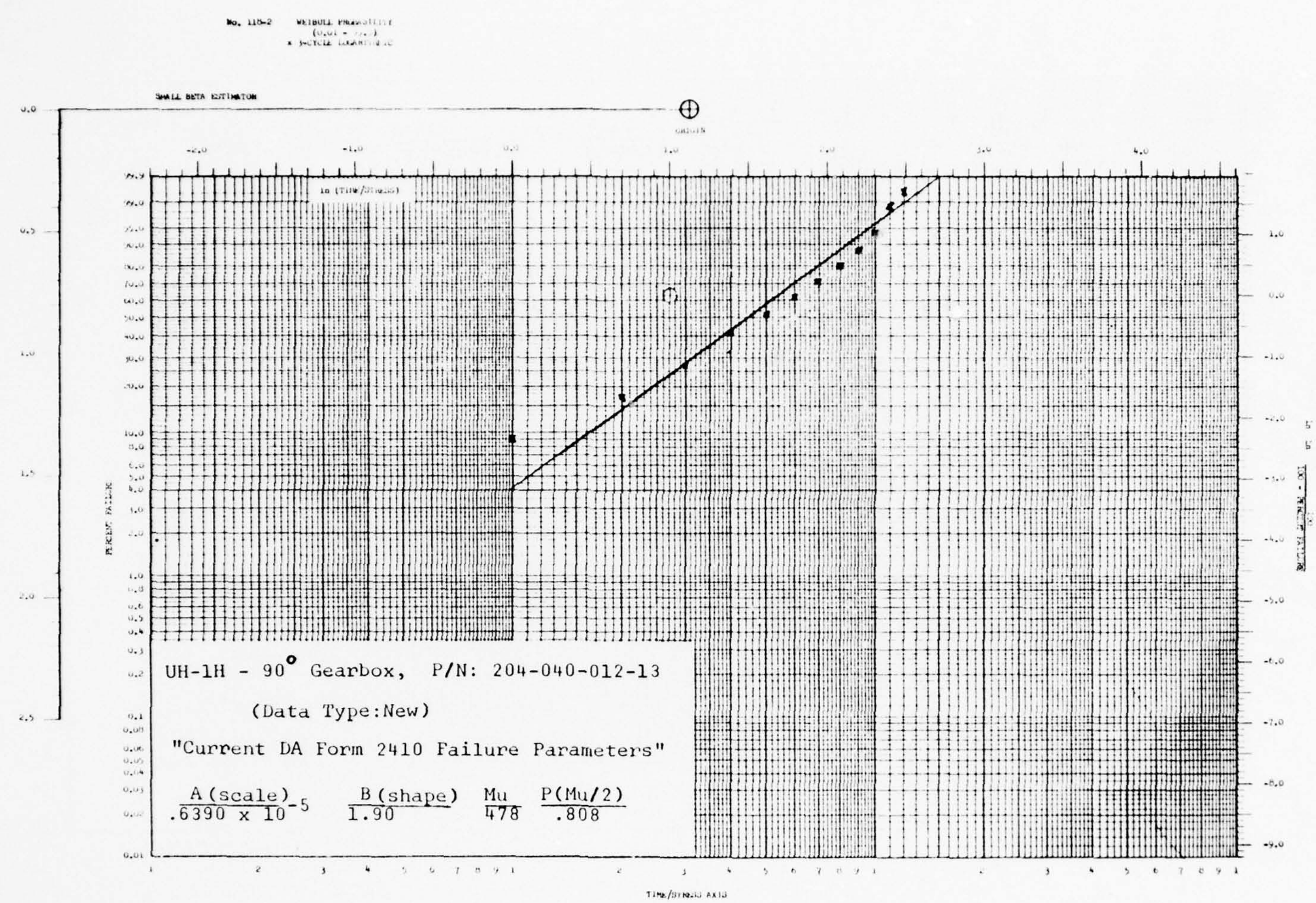

SMALL BETA ESTIMATOR
ORIGIN
TIME/STRESS AXIS
AH-1G/UH-1H - 42° Gearbox, P/N: 204-040-003-37
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A (scale) .5933 x 10^-4
B (shape) 1.49
Mu 625
P(Mu/2) .736

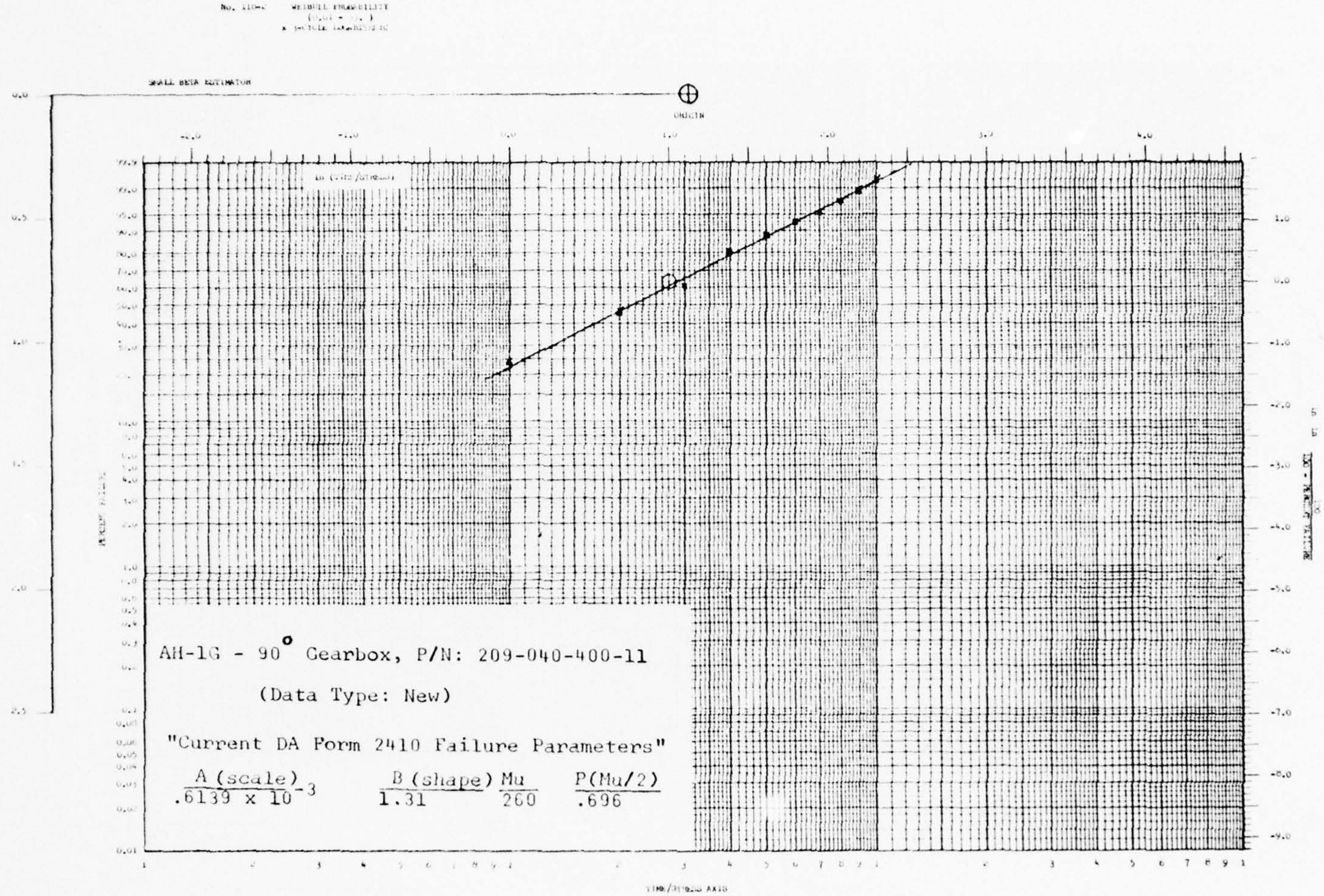

SMALL BETA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS
UH-1H - 90° Gearbox, P/N: 204-040-012-13
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .6925 x 10-4
B(shape) 1.53
Mu 476
P(Mu/2) .744

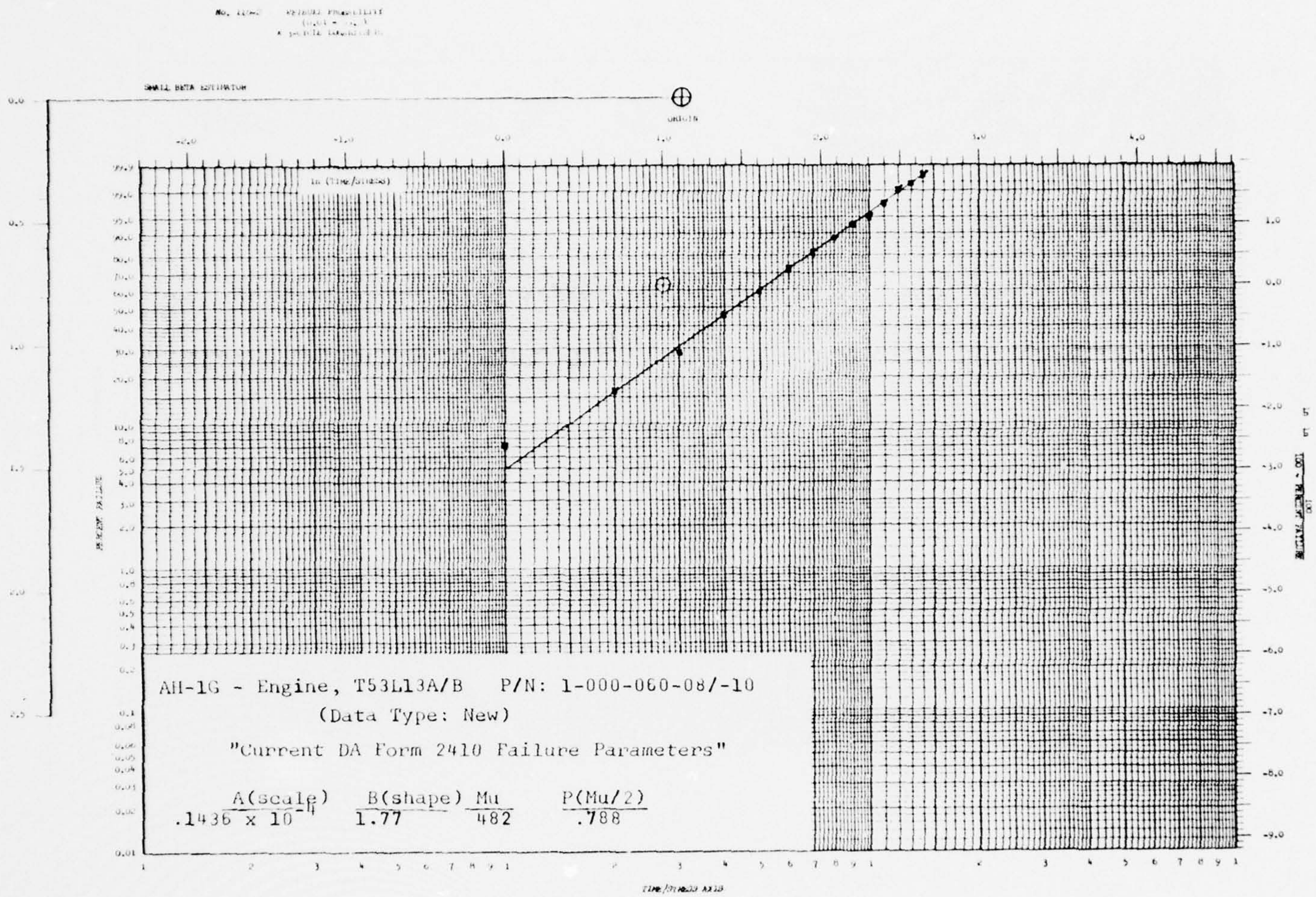

UH-1H - 90° Gearbox, P/N: 204-040-012-13
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A(scale) B(shape)Mu P(Mu/2)
.7901 x 10-4 1.57 .371 .752

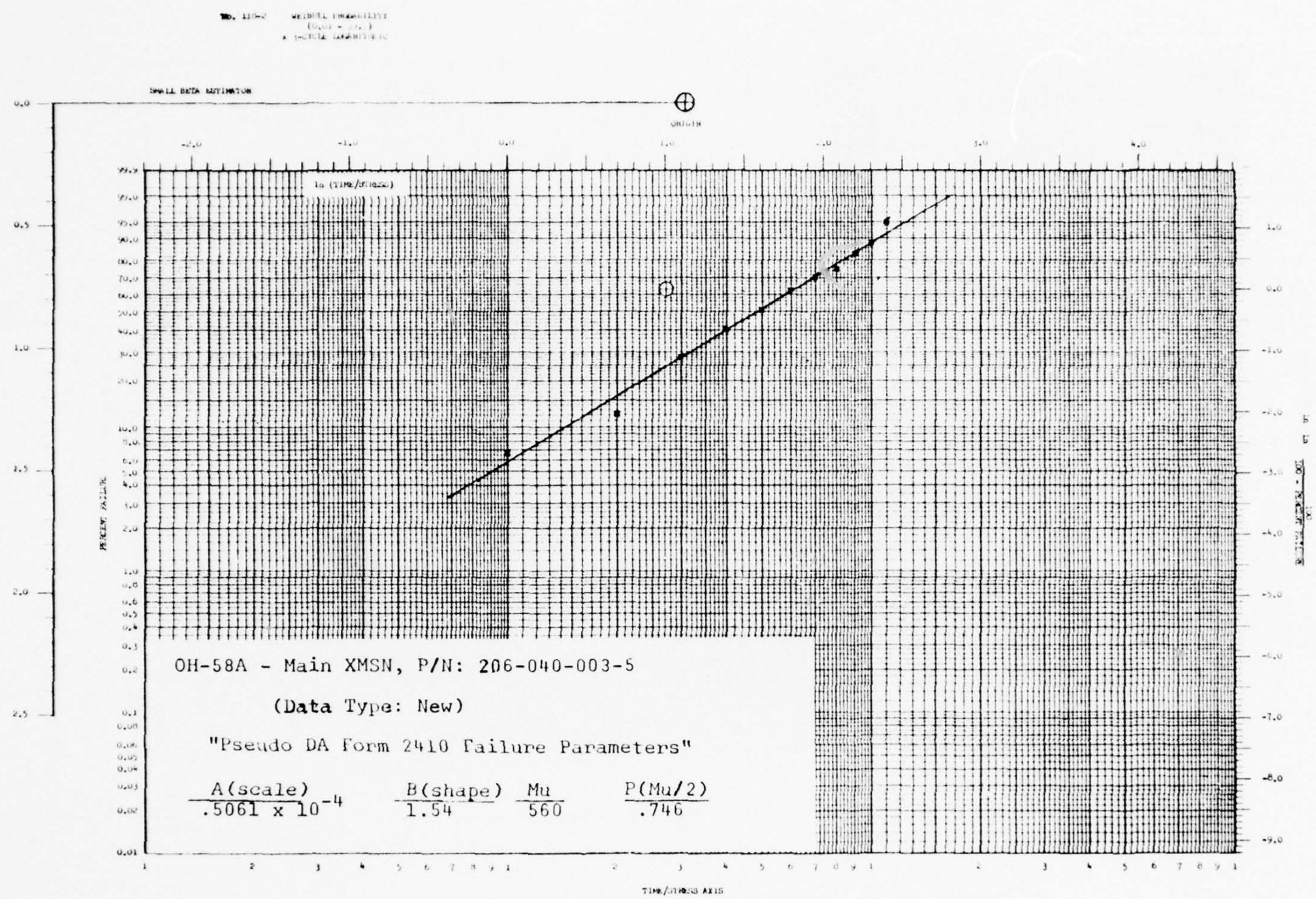


SMALL DATA ESTIMATOR
ORIGIN
PERCENT FAILURE
ln (TIME/STRESS)
TIME/STRESS AXIS
UH-1H - 90° Gearbox, P/N: 204-040-012-13
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A (scale) .1866 x 10^-4
B (shape) 1.71
Mu 517
P(Mu/2) 0.778

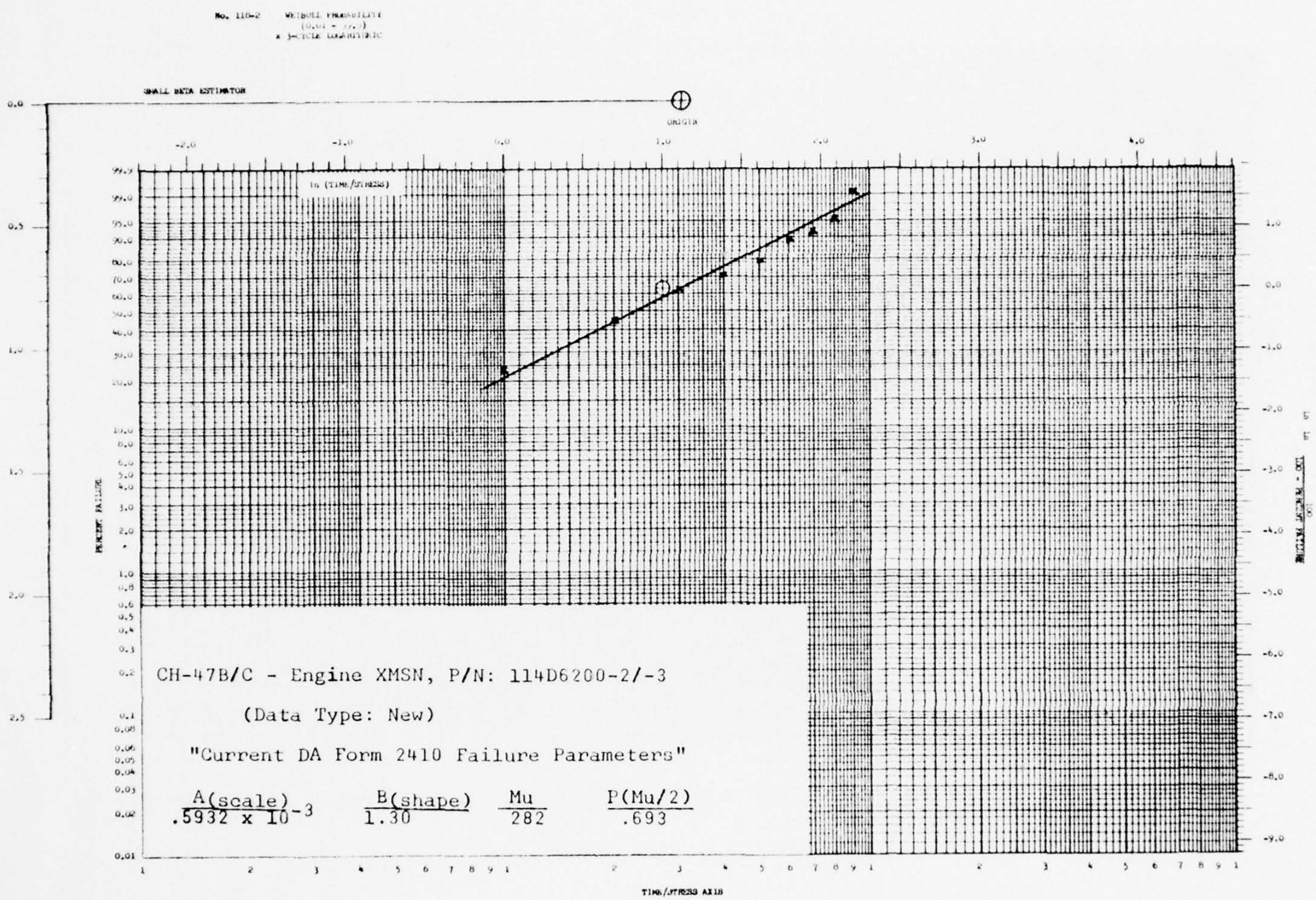

SMALL BETA ESTIMATION
PERCENT FAILURE
TIME/STRESS AXIS
ln (TIME/STRESS)
UH-1H - 90° Gearbox, P/N: 204-040-012-13
(Data Type:New)
"Current DA Form 2410 Failure Parameters"
A(scale) .6390 x 10-5
B(shape) 1.90
Mu 478
P(Mu/2) .808


AH-1G - 90° Gearbox, P/N: 209-040-400-11
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A (scale) .6139 x 10^{-3}
B (shape) 1.31
Mu 260
P(Mu/2) .696

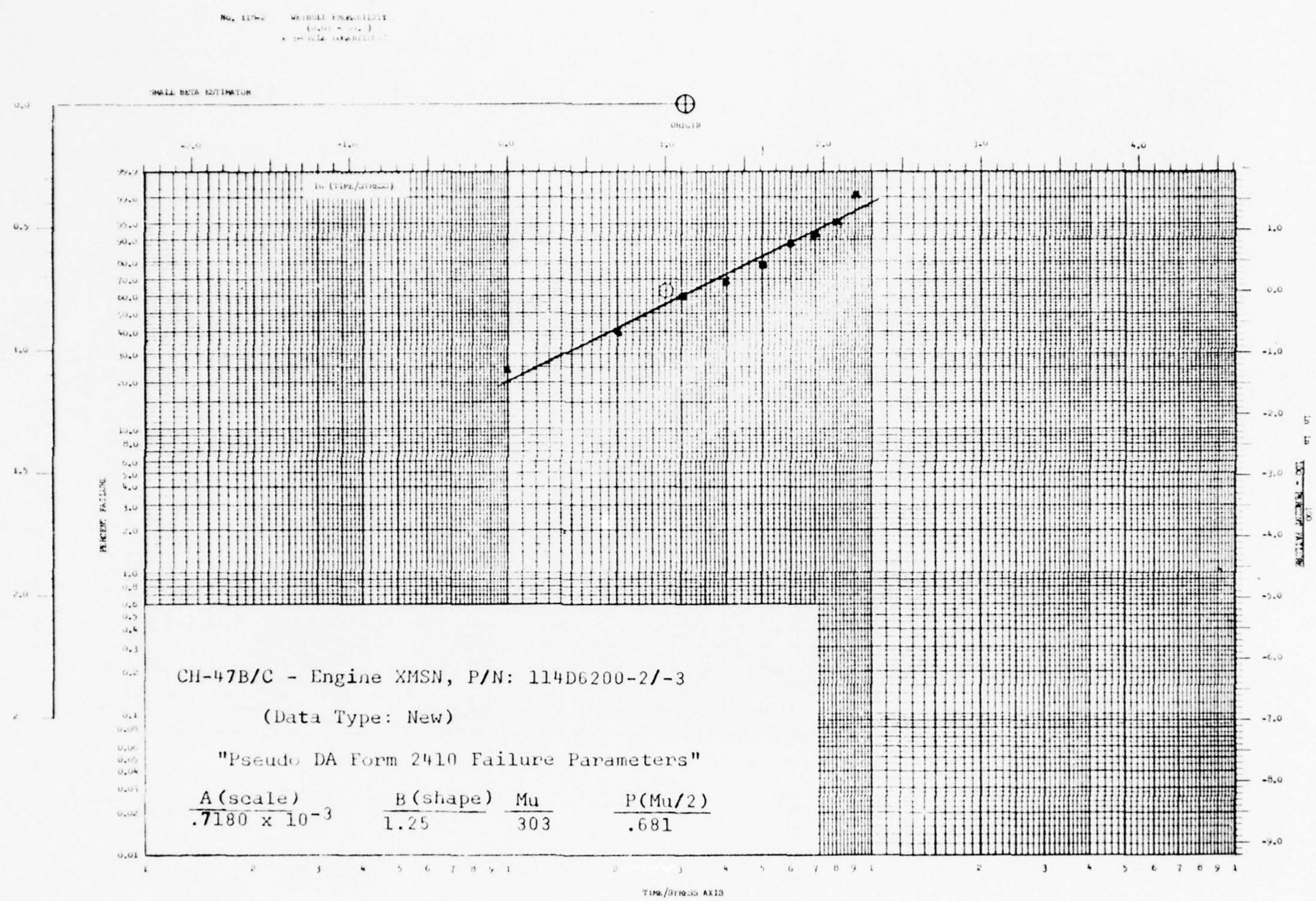

SMALL BETA ESTIMATOR
ORIGIN
ln (Time/Stress)
PERCENT FAILURE
TIME/STRESS AXIS
AH-1G - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A(scale) B(shape) Mu P(Mu/2)
.1436 x 10^-4 1.77 482 .788

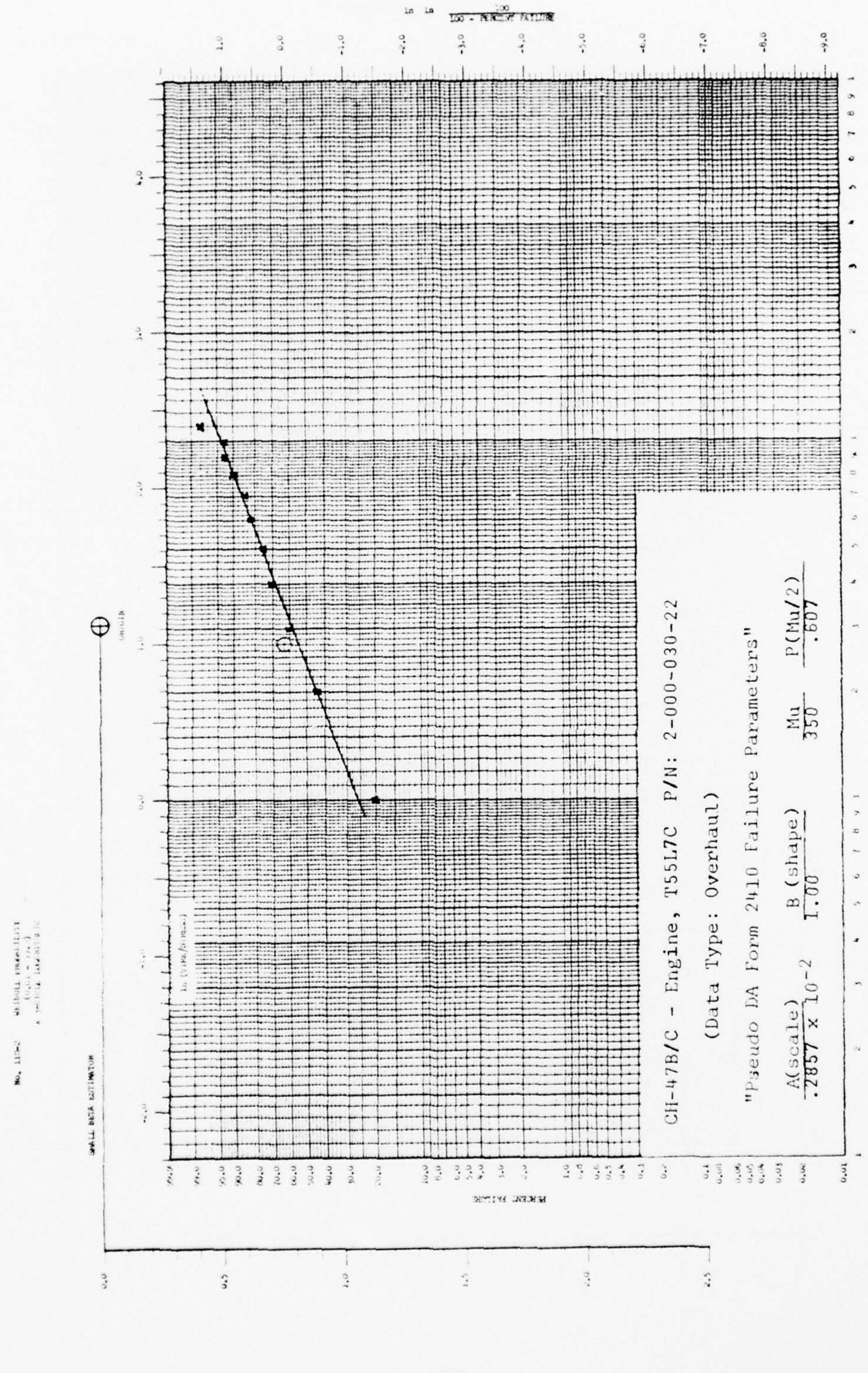


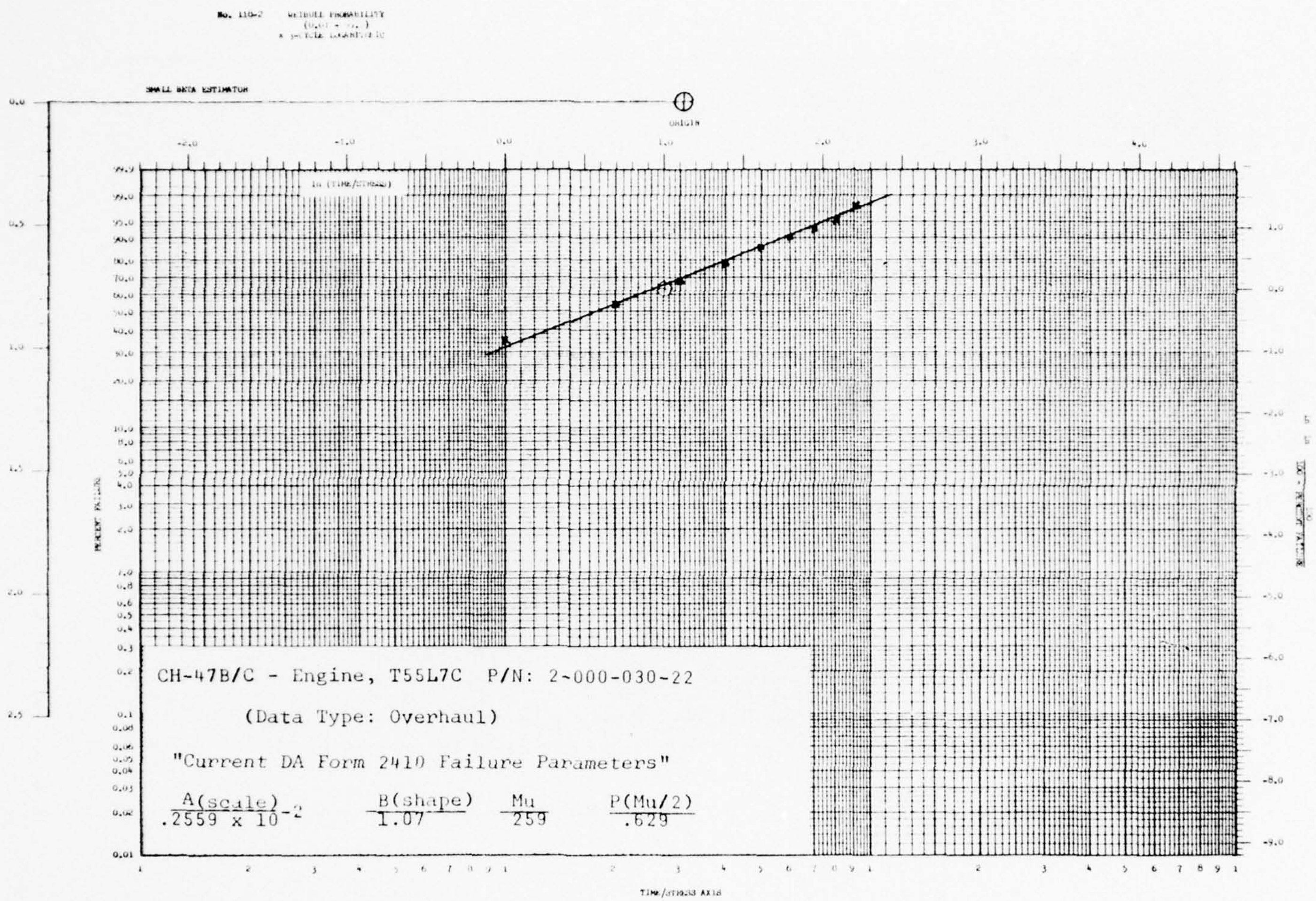
OH-58A - Main XMSN, P/N: 206-040-003-5
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .5061 x 10^-4
B(shape) 1.54
Mu 560
P(Mu/2) .746

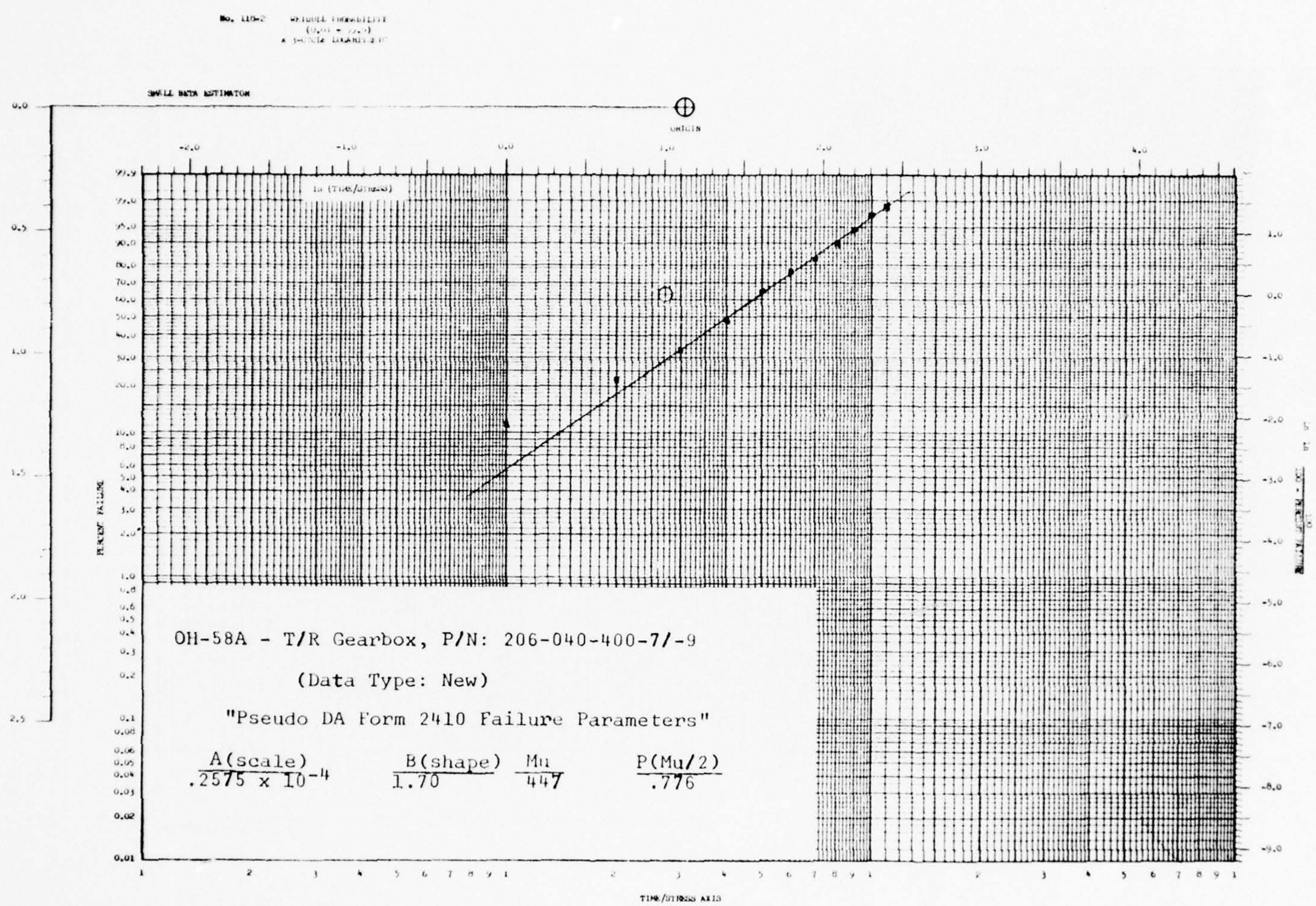


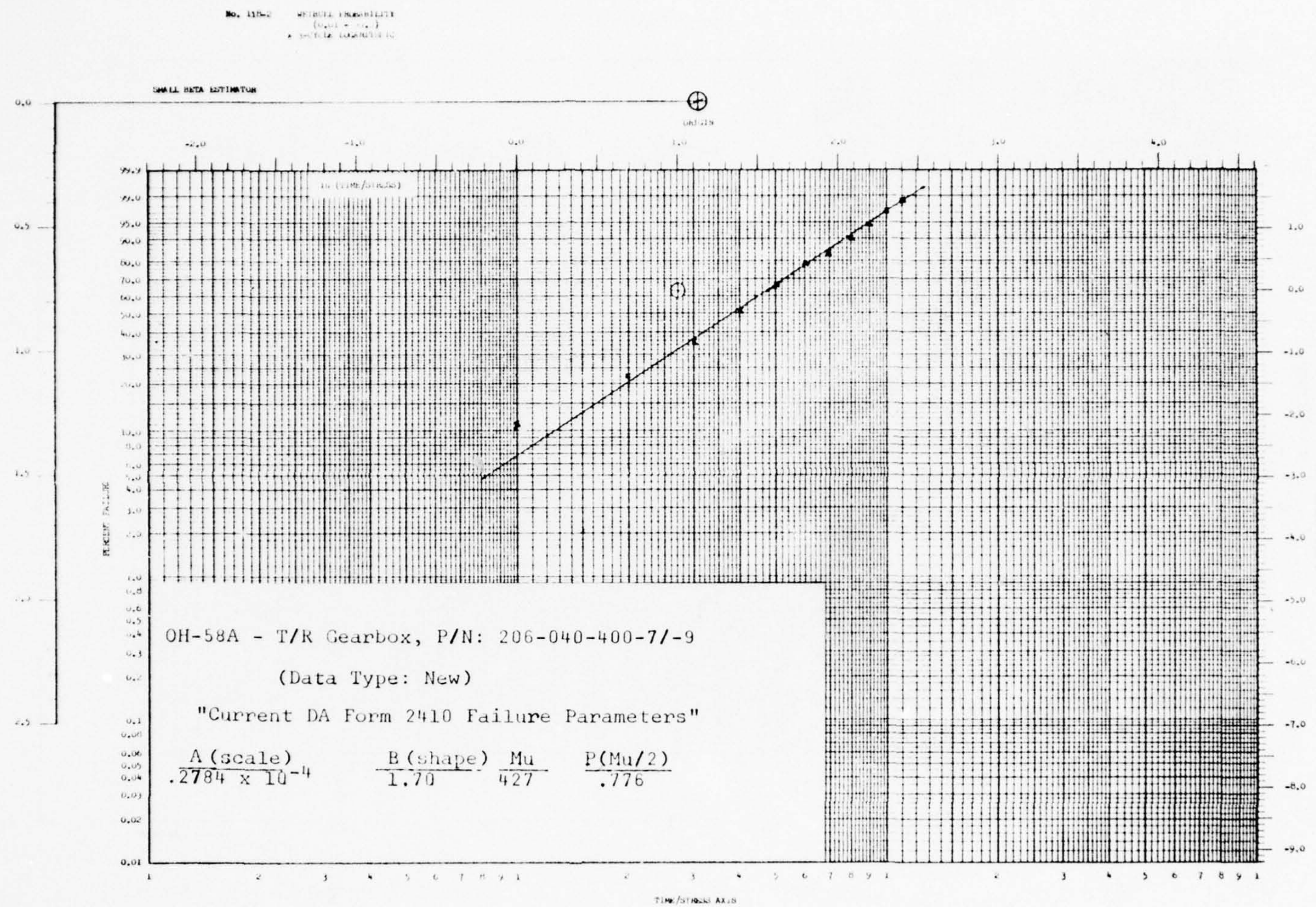
No. 110-2 WEIBULL PROBABILITY
SMALL BETA ESTIMATOR
ORIGIN
ln (TIME/STRESS)
PERCENT FAILURE
TIME/STRESS AXIS
CH-47B/C - Engine XMSN, P/N: 114D6200-2/-3
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A(scale) .5932 x 10-3
B(shape) 1.30
Mu 282
P(Mu/2) .693

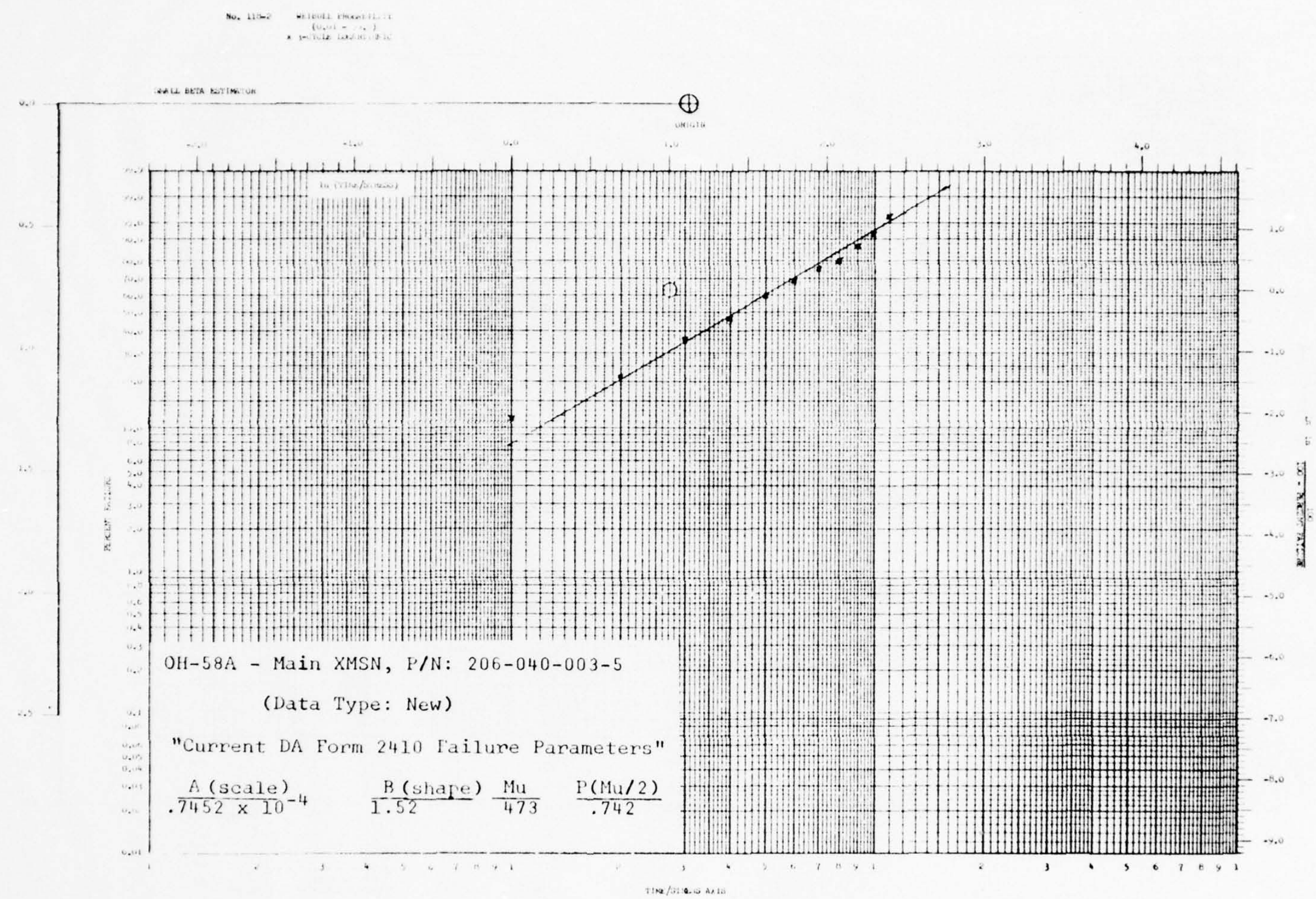

CH-47B/C - Engine XMSN, P/N: 114D6200-2/-3
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A (scale)
.7180 x 10-3
B (shape)
1.25
Mu
303
P(Mu/2)
.681
SMALL BETA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS

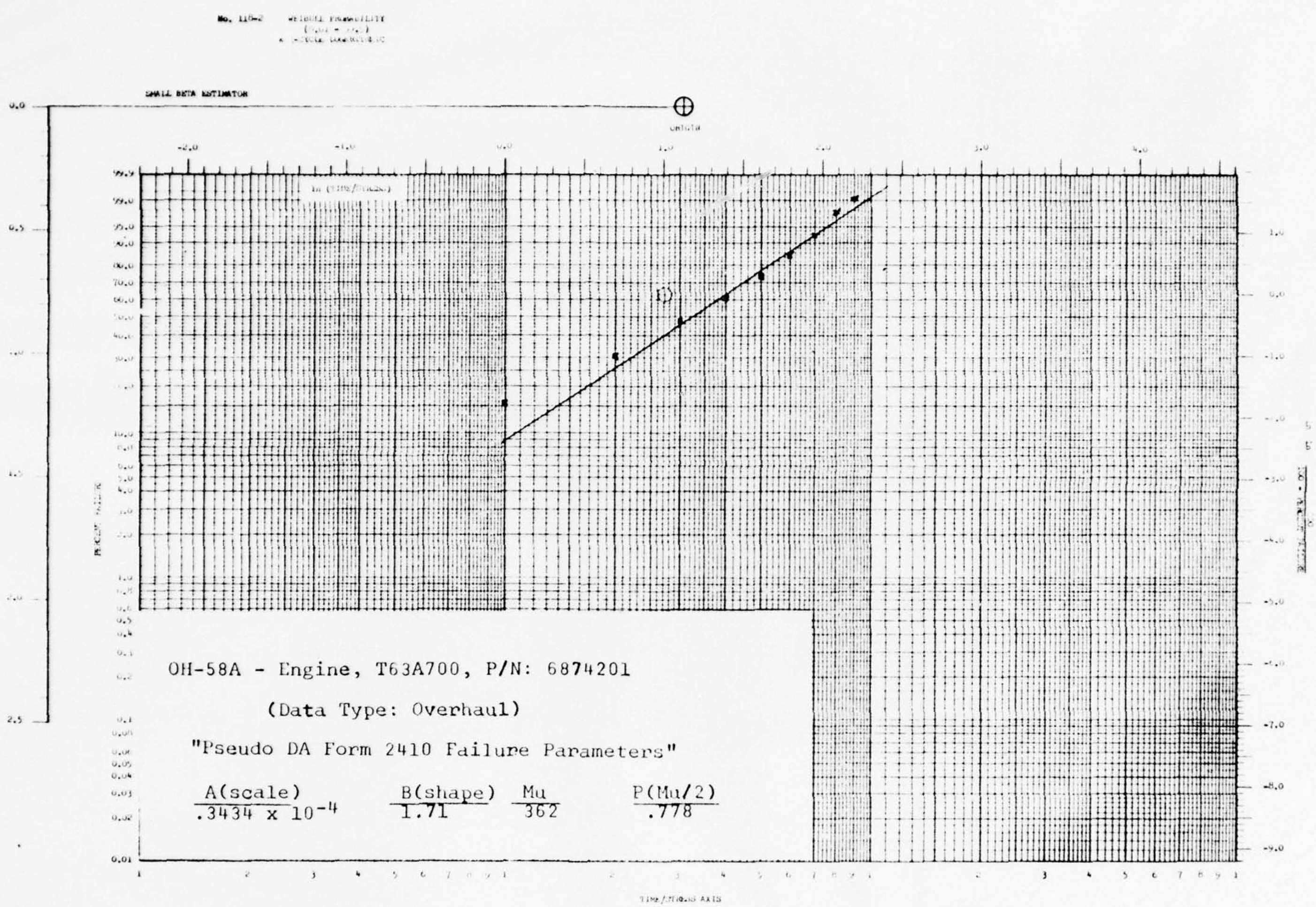

CH-47B/C - Engine, T55L7C P/N: 2-000-030-22
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A(scale)
.2857 x 10-2
B (shape)
1.00
Mu
350
P(Mu/2)
.607

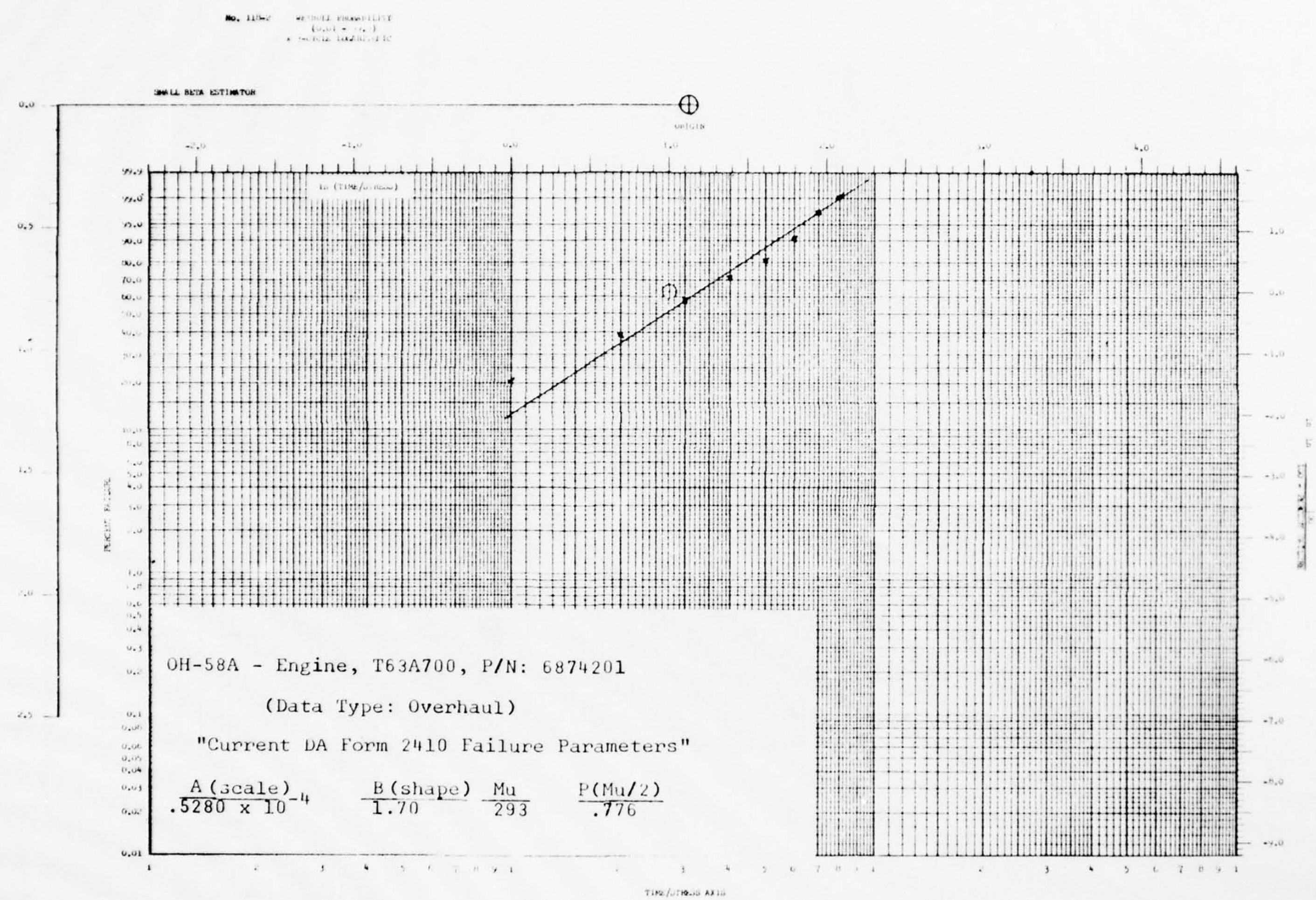

SMALL BETA ESTIMATOR
ORIGIN
CH-47B/C - Engine, T55L7C P/N: 2-000-030-22
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A(scale) .2559 x 10^-2
B(shape) 1.07
Mu 259
P(Mu/2) .629
TIME/STRESS AXIS


SMALL DATA ESTIMATOR
ORIGIN
ln (TIME/STRESS)
PERCENT FAILURE
TIME/STRESS AXIS
OH-58A - T/R Gearbox, P/N: 206-040-400-7/-9
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .2575 x 10-4
B(shape) 1.70
Mu 447
P(Mu/2) .776


SMALL BETA ESTIMATOR
PERCENT FAILURE
TIME/STRESS AXIS
OH-58A - T/R Gearbox, P/N: 206-040-400-7/-9
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A (scale) .2784 x 10^-4
B (shape) 1.70
Mu 427
P(Mu/2) .776


OH-58A - Main XMSN, P/N: 206-040-003-5
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A (scale) .7452 x 10-4
B (shape) 1.52
Mu 473
P(Mu/2) .742
TIME/STRESS AXIS


OH-58A - Engine, T63A700, P/N: 6874201
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .3434 x 10^-4
B(shape) 1.71
Mu 362
P(Mu/2) .778


SMALL BETA ESTIMATOR
ORIGIN
TIME/STRESS AXIS
OH-58A - Engine, T63A700, P/N: 6874201
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A (scale) .5280 x 10^-4
B (shape) 1.70
Mu 293
P(Mu/2) .776

AD-A059 846 COBRO CORP SILVER SPRING MD F/G 1/3
EVALUATION OF AIRCRAFT EQUIPMENT MONITORING DEVICES, PROCEDURES--ETC(U)
JUL 78 J E MARSH DAAJ02-77-C-0052
UNCLASSIFIED TR-11-3 USARTL-TR-78-31 NL

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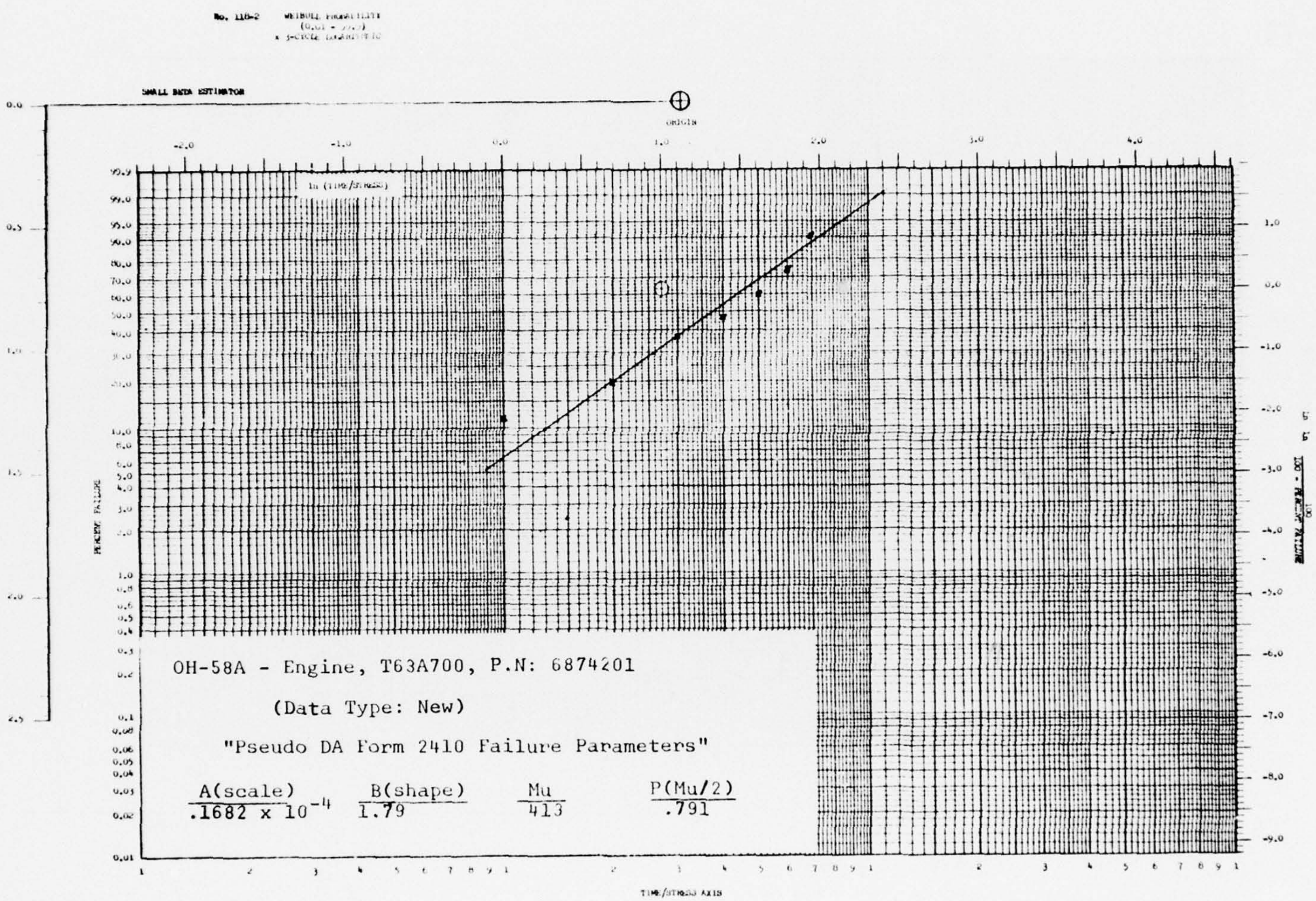
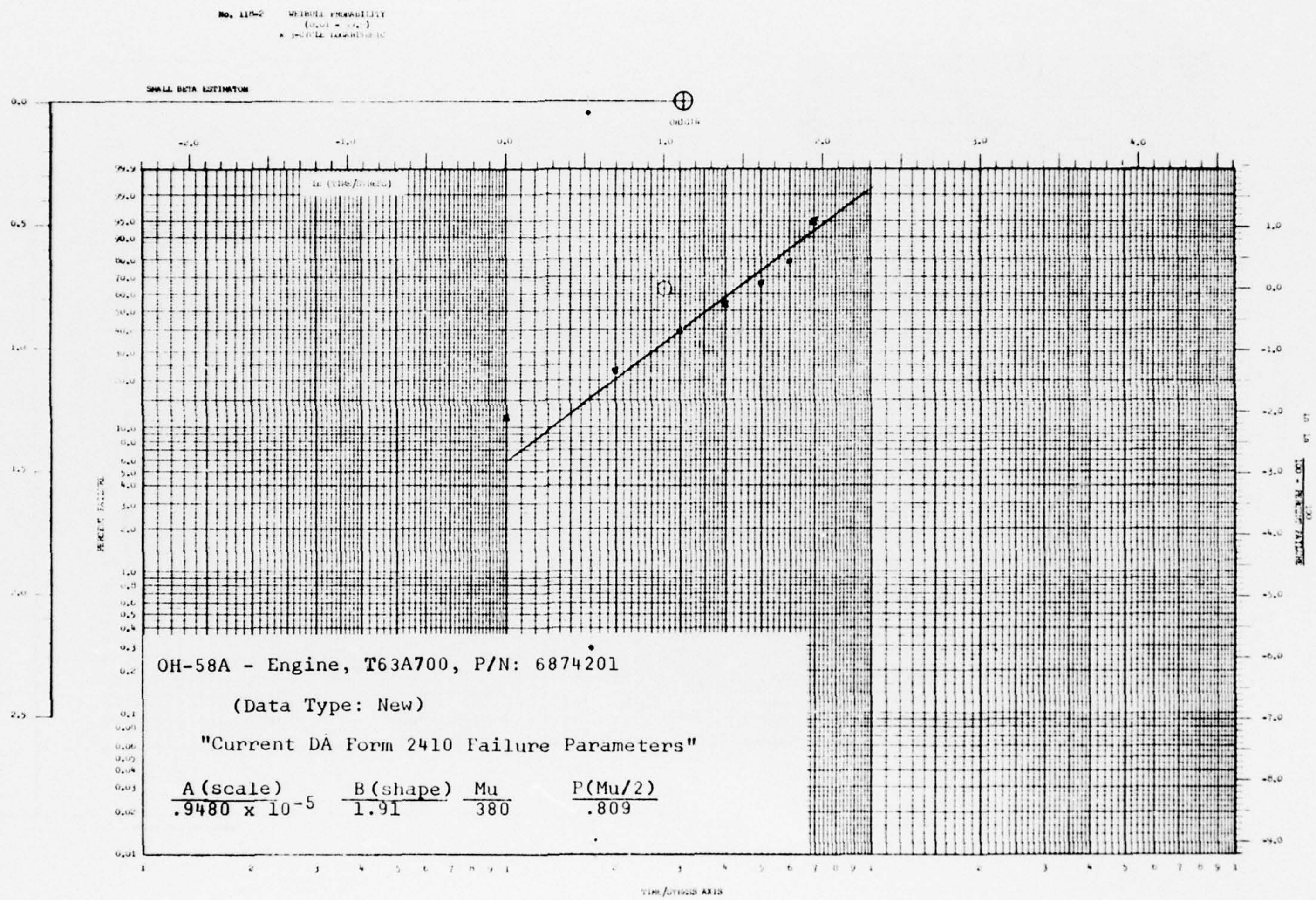
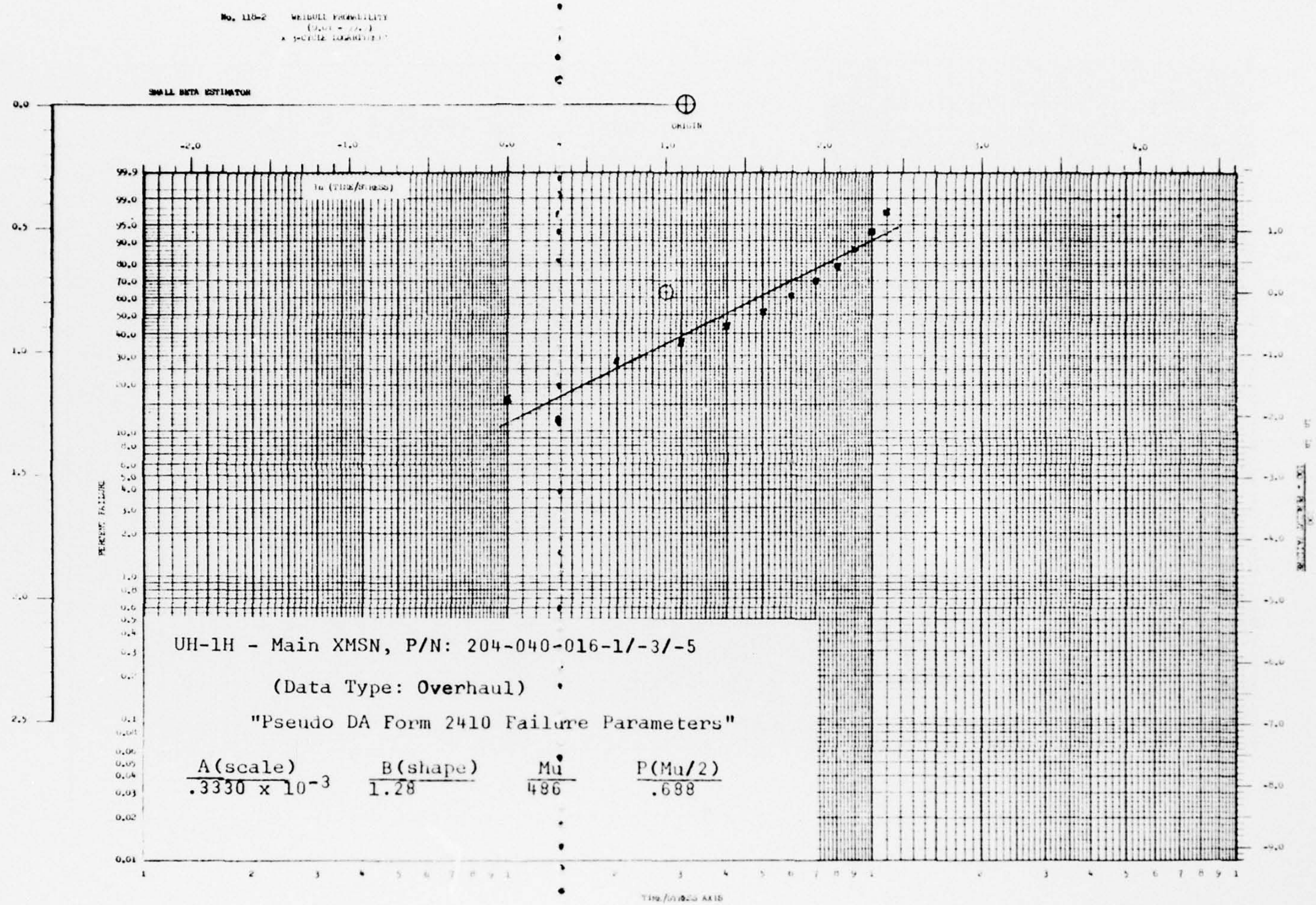
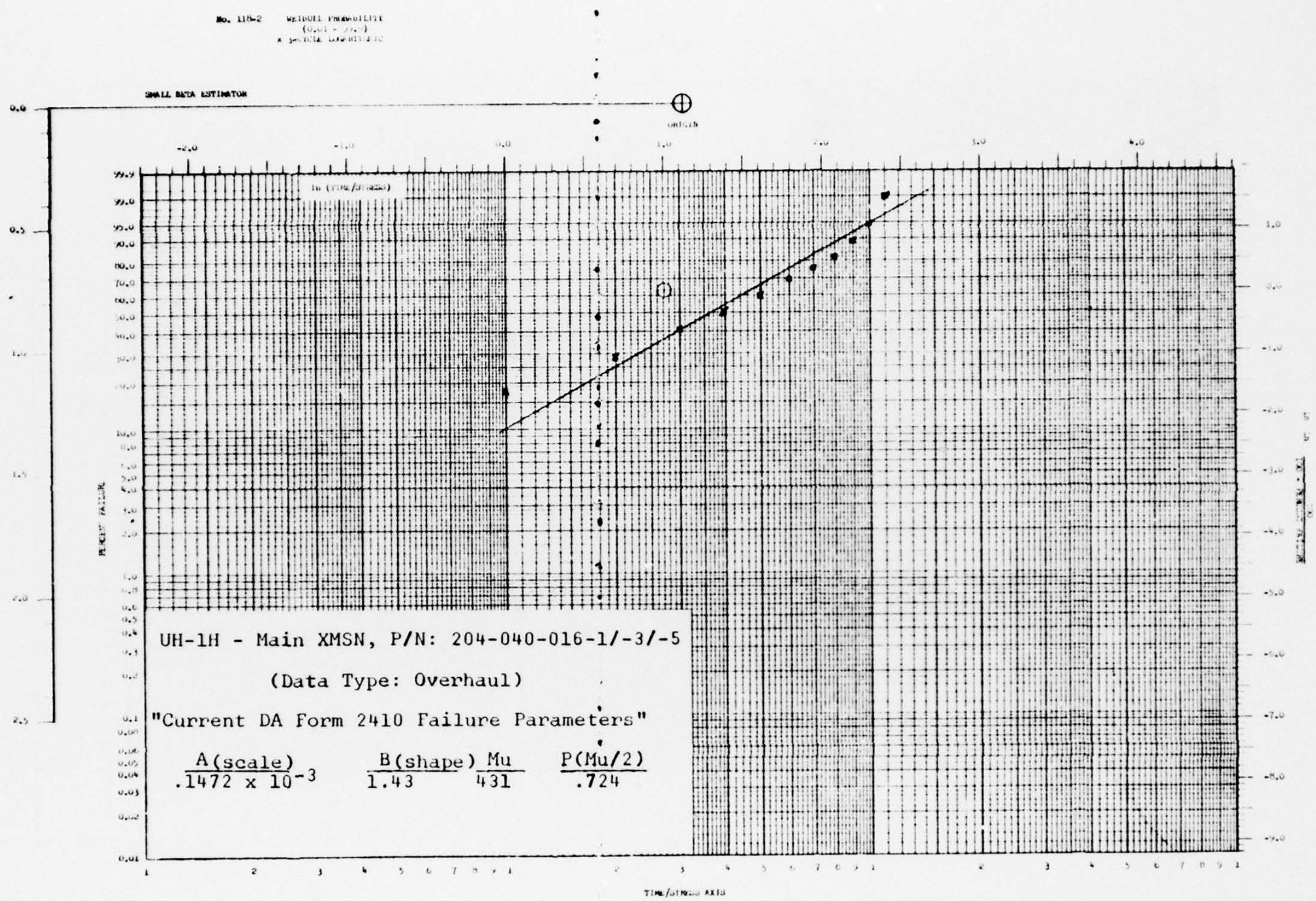
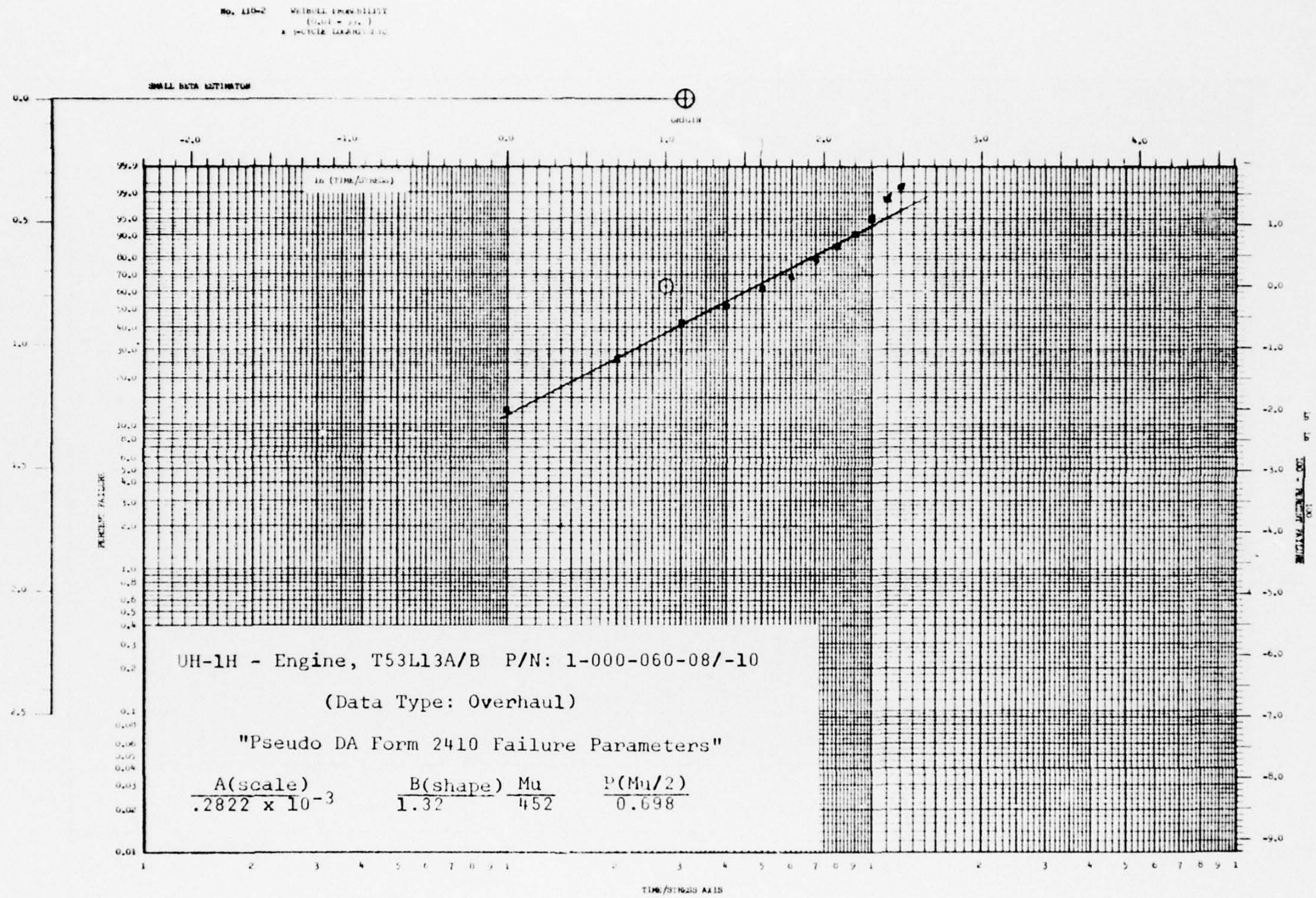
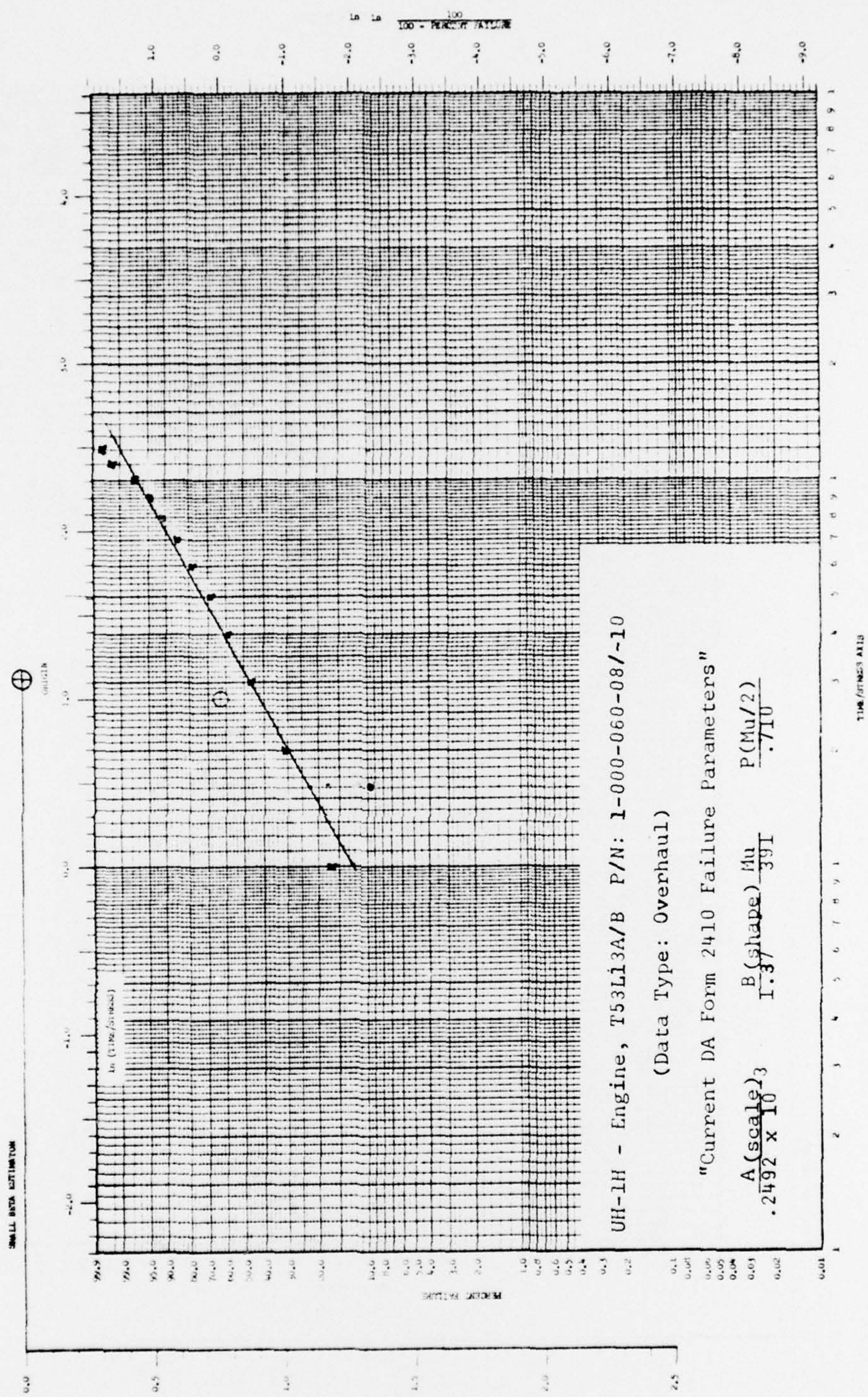

No. 118-2 WEIBULL PROBABILITY
SMALL DATA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS
OH-58A - Engine, T63A700, P.N: 6874201
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .1682 x 10^-4
B(shape) 1.79
Mu 413
P(Mu/2) .791

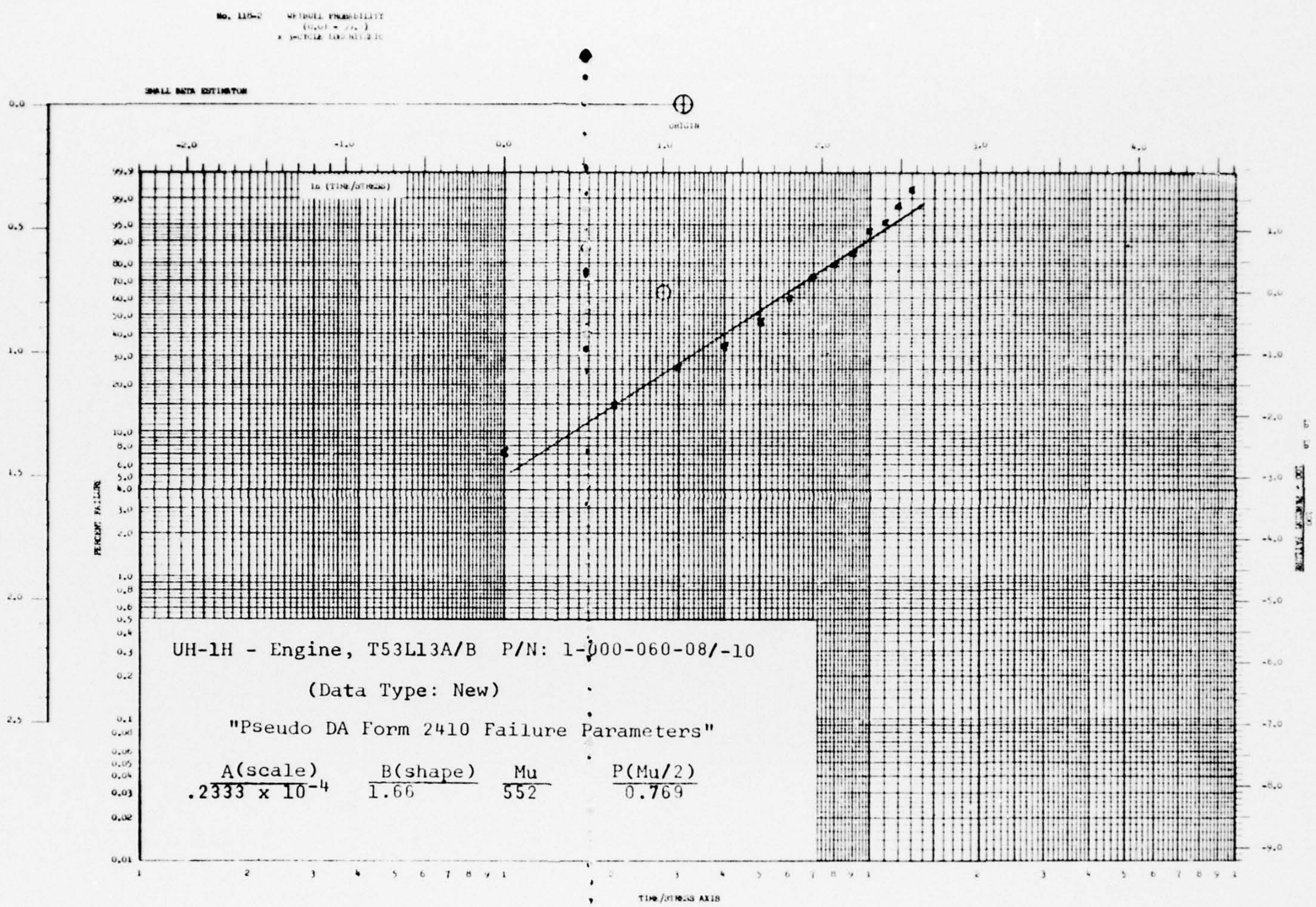

No. 110-2 WEIBULL PROBABILITY
SMALL BETA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS
OH-58A - Engine, T63A700, P/N: 6874201
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A (scale) .9480 x 10-5
B (shape) 1.91
Mu 380
P(Mu/2) .809

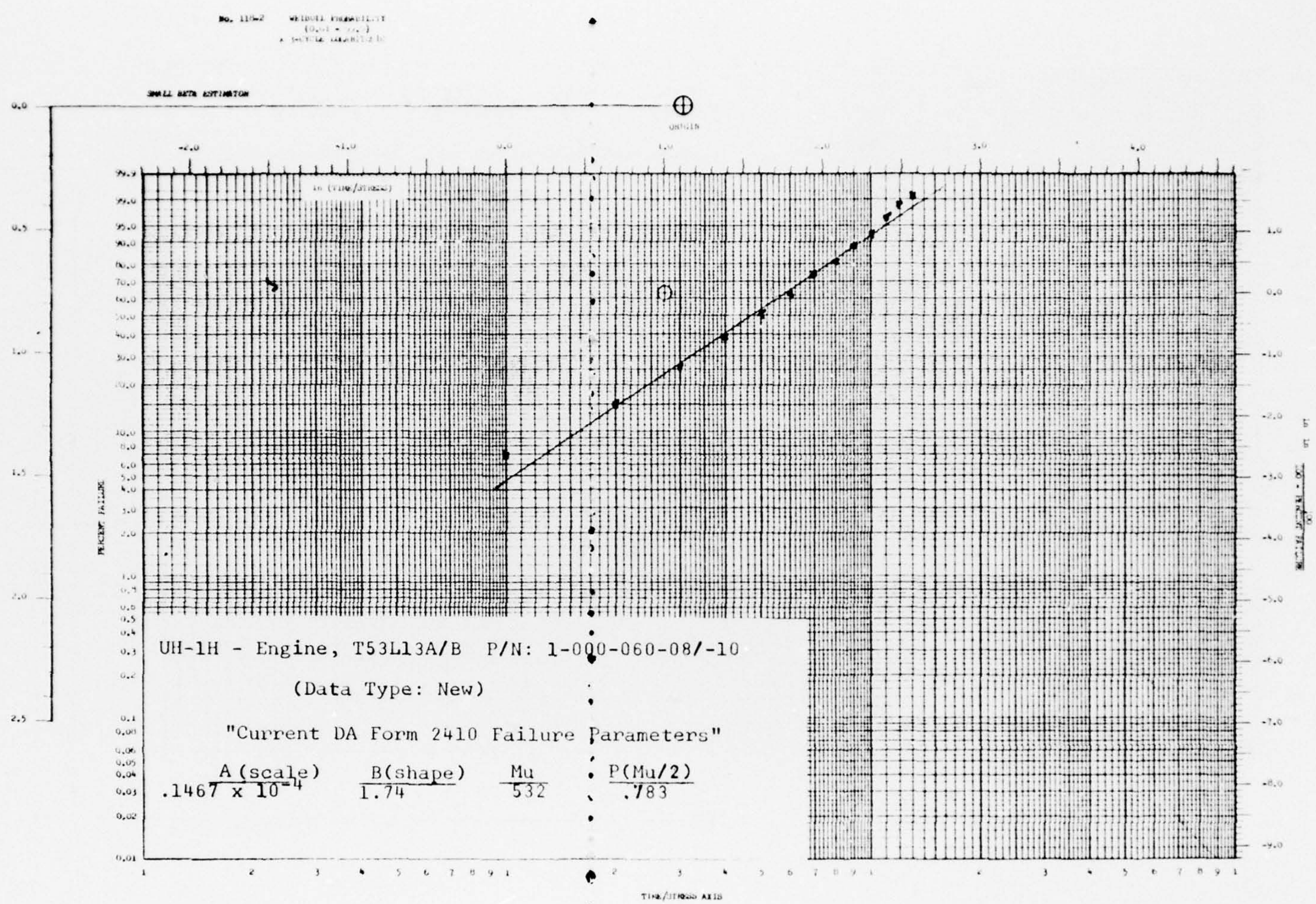

UH-1H - Main XMSN, P/N: 204-040-016-1/-3/-5
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .3330 x 10-3
B(shape) 1.28
Mu 486
P(Mu/2) .688

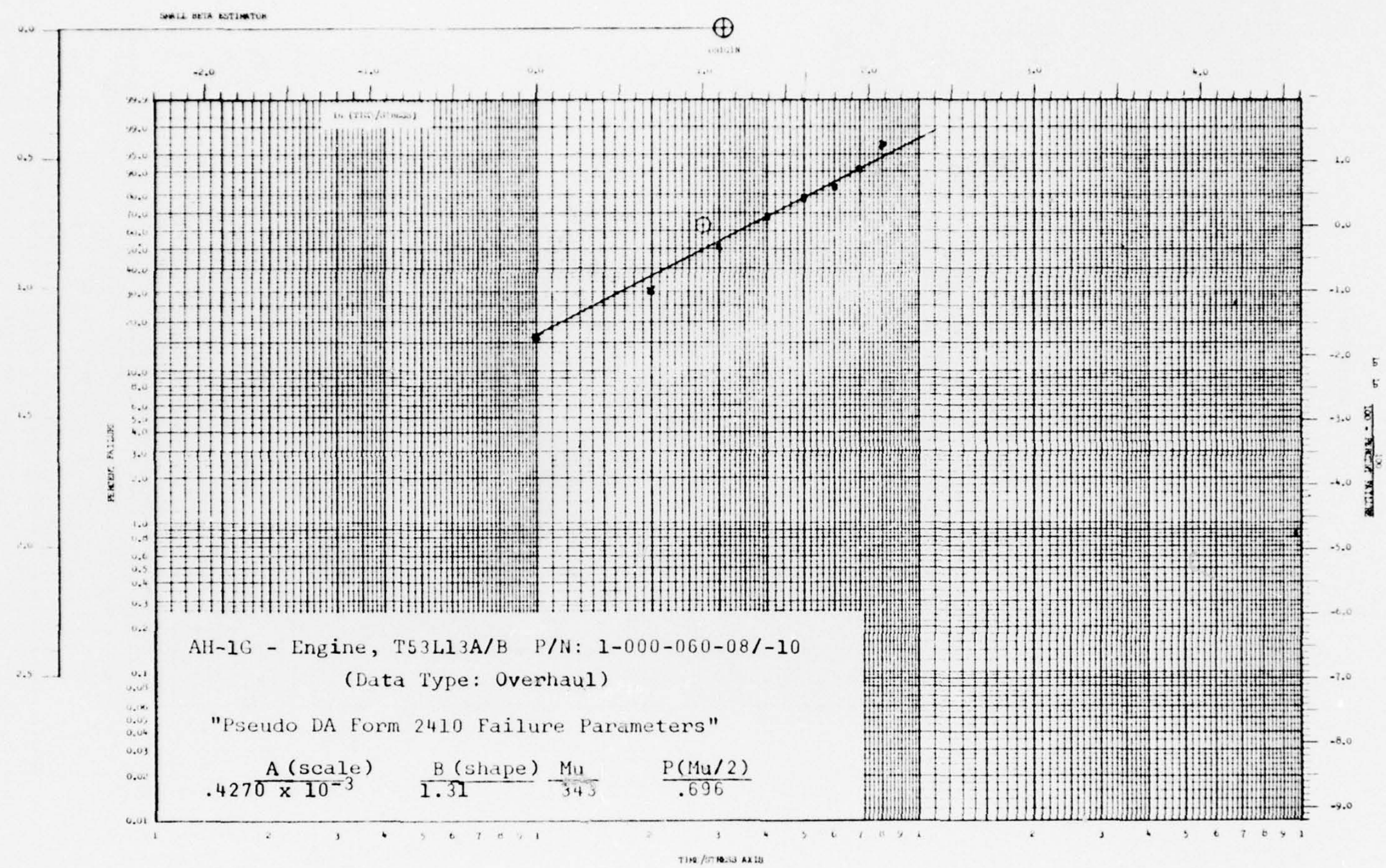

SMALL DATA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS
UH-1H - Main XMSN, P/N: 204-040-016-1/-3/-5
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A(scale) .1472 x 10-3
B(shape) 1.43
Mu 431
P(Mu/2) .724

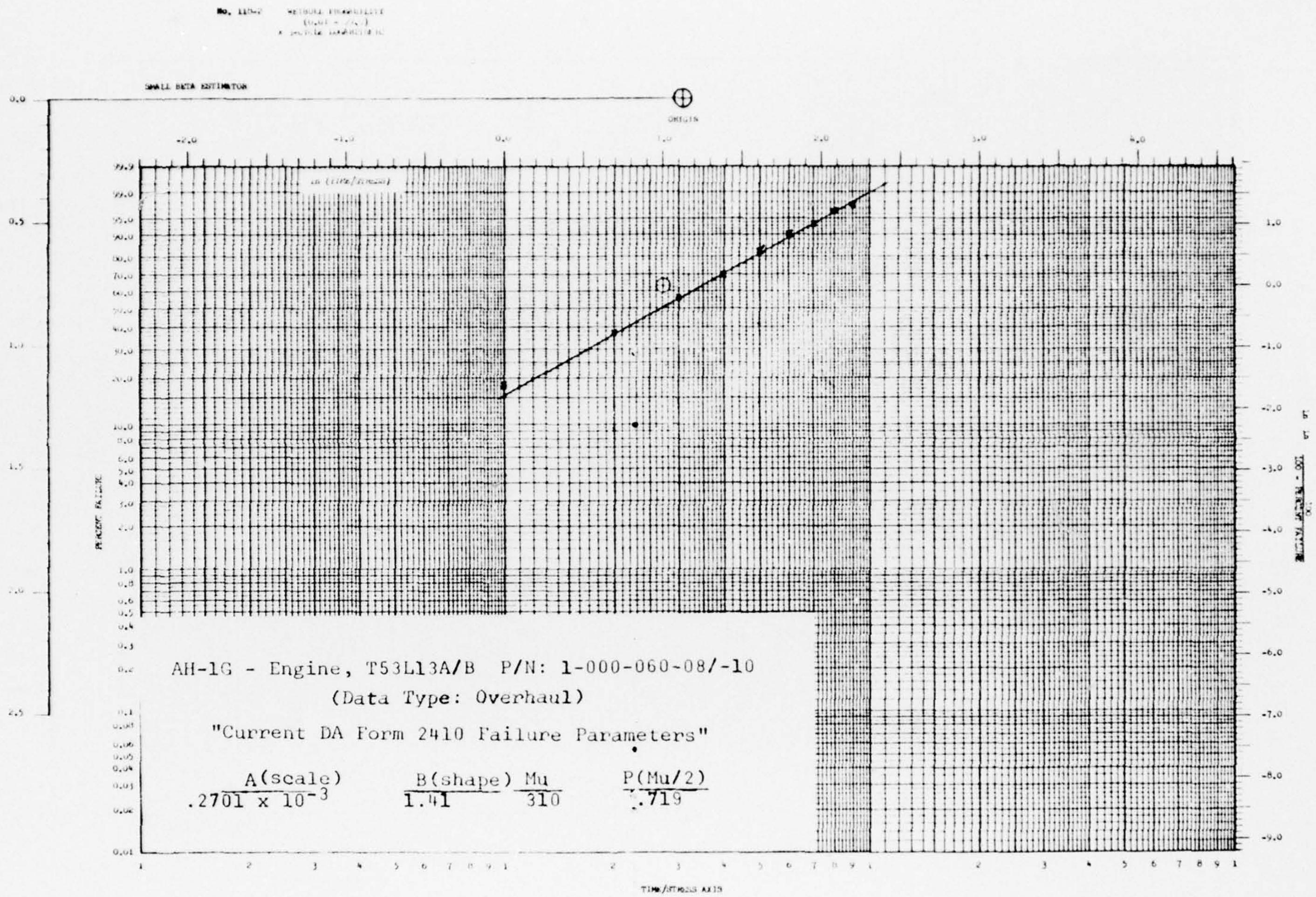

SMALL DATA ESTIMATOR
UH-1H - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .2822 x 10-3
B(shape) 1.32
Mu 452
P(Mu/2) 0.698
TIME/STRESS AXIS

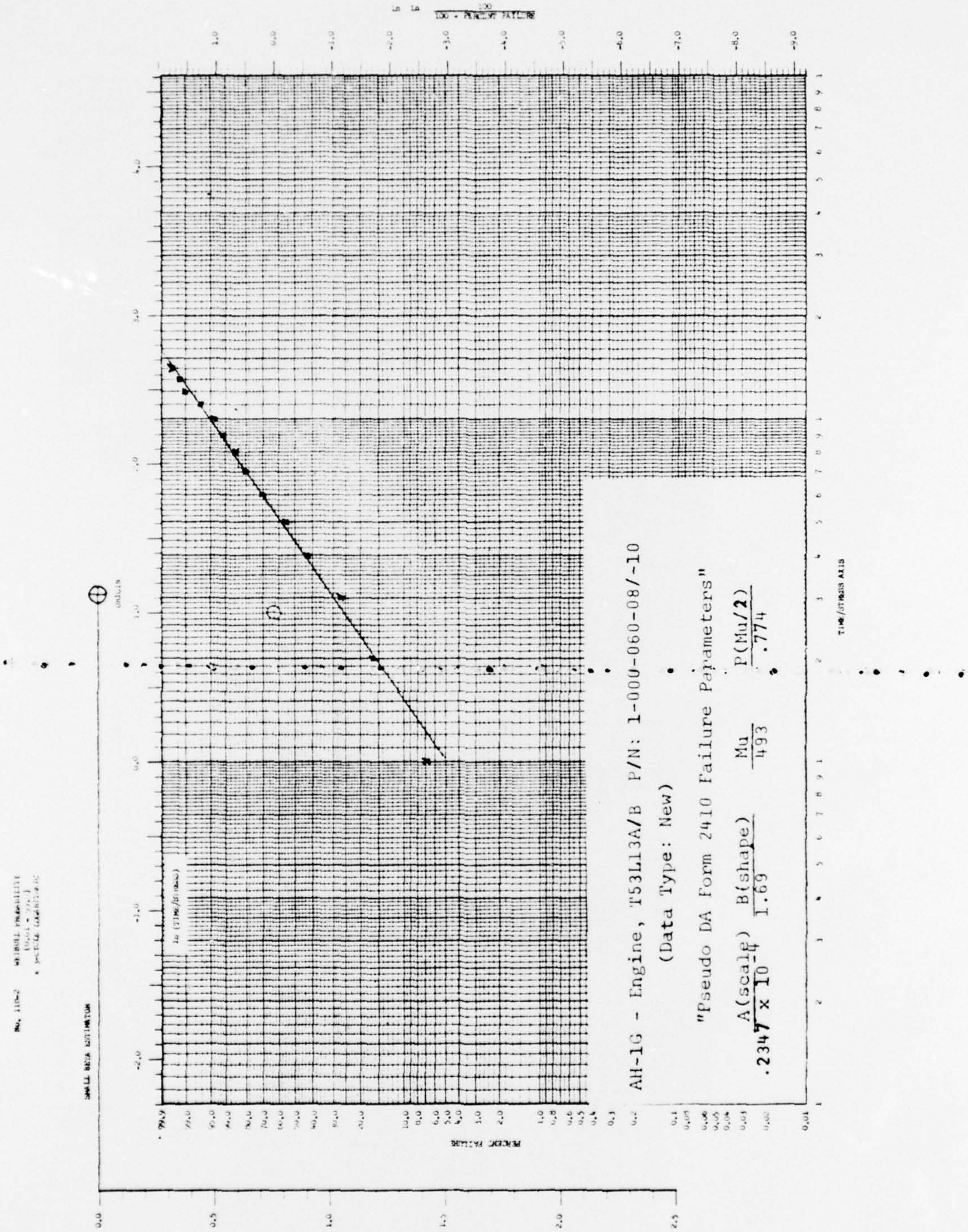

UH-1H - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A(scale) .2492 x 10 3
B(shape) 1.37
Mu 391
P(Mu/2) .710


No. 116-2 WEIBULL PROBABILITY
SMALL DATA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS
UH-1H - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) .2333 x 10-4
B(shape) 1.66
Mu 552
P(Mu/2) 0.769


UH-1H - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: New)
"Current DA Form 2410 Failure Parameters"
A (scale) .1467 x 10^-4
B(shape) 1.74
Mu 532
P(Mu/2) .783


AH-1G - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: Overhaul)
"Pseudo DA Form 2410 Failure Parameters"
A (scale) .4270 x 10^-3
B (shape) 1.31
Mu 343
P(Mu/2) .696


SMALL BETA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS
AH-1G - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: Overhaul)
"Current DA Form 2410 Failure Parameters"
A(scale)
.2701 x 10-3
B(shape)
1.41
Mu
310
P(Mu/2)
.719



AH-1G - Engine, T53L13A/B P/N: 1-000-060-08/-10
(Data Type: New)
"Pseudo DA Form 2410 Failure Parameters"
A(scale) B(shape) Mu P(Mu/2)
.2347 x 10-4 1.69 493 .774
SMALL BETA ESTIMATOR
ORIGIN
PERCENT FAILURE
TIME/STRESS AXIS

APPENDIX C
LIST OF ACRONYMS

A - Scale parameter of the two parameter Weibull probability density function

AMSEC - Analytical Methodology for System Evaluation and Control

AOAP - Army Oil Analysis Program

ATL - Applied Technology Laboratory

AVIM - Aviation Intermediate Maintenance

AVRADCOM - Army Aviation Research and Development Command

AVUM - Aviation Unit Maintenance

B - Shape parameter of the two parameter Weibull probability density function

D&CM - Diagnostic and Condition Monitoring

DA - Department of the Army

DIR - Disassembly Inspection Report

EIR - Equipment Improvement Recommendation

FIT - First Indication of Trouble

HIT - Health Indication Test

MIRF - Major Item Removal Frequency

MTBUR - Mean Time Between Unscheduled Removals

O&S - Operational and Support

QC - Quality Control

R/A/C - Reliability/Availability/Cost

RAM/LOG - Reliability Availability Maintainability/Logistics

RAMMIT - Reliability and Maintainability Management Improvement Techniques

APPENDIX C (CON'T)

TAMMS - The Army Maintenance Management System

TBO - Time Between Overhaul

TSARCOM - Troop Support and Readiness Command

USAAAVS - United States Army Agency for Aviation Safety

USAATL - United States Army Applied Technology Laboratory

XMSN - Transmission